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FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

ITEMS AND NOVELTIES.

Tank for Continuously Measuring Feed Water.—We herewith present illustrations of the tank used during the experiments with the U. S. coast survey steamer "Bache," set forth in the report of consulting engineer Chas. E. Emery, published in the February number of this JOURNAL. An almost identical system was adopted in the experiments with the U. S. revenue steamers, as set forth in the report of chief engineer Loring, U. S. N., and consulting engineer Emery, which appears in the present number.*

Figure 1 is a side elevation, and Figure 2, a plan of the tank which is shown erected on blocks of wood. The tank is divided into two parts by a central partition (B) of less height than the outer walls. During the experiments the tank was placed on the main deck, in the gangway abreast of the engine, and the feed water delivered to the same directly by the air pump, through a pipe with a flexible termination (C), which could be directed over either compartment (A, A′) of tank. A pipe (E) with two branches (G, G′) and regulating cock (D, D′) in each, conducted the water from the two compartments re-

*Further explanation will be found in the reports referred to.

spectively, to a tank in the hold, from which the water was withdrawn by the engine feed pumps.

Fig. 1

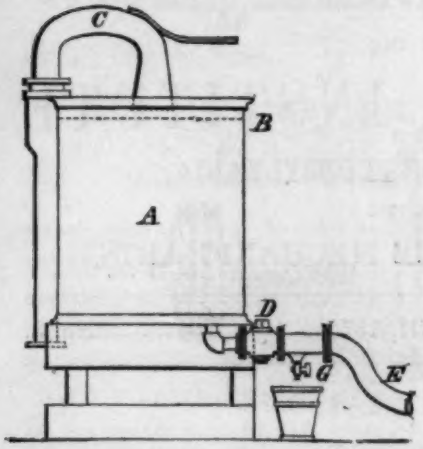
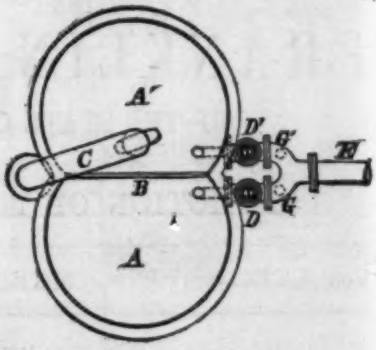


Fig. 2.



The measurement was made by filling one compartment (A), for instance, till it over-flowed into the other (A′), which had been previously emptied; the supply was then changed to the latter (A′), and when the surplus water in first (A) had run off, that compartment was emptied and cock on bottom of same closed in time to receive the overflow from the other (A′); the operation being repeated alternately with each compartment.

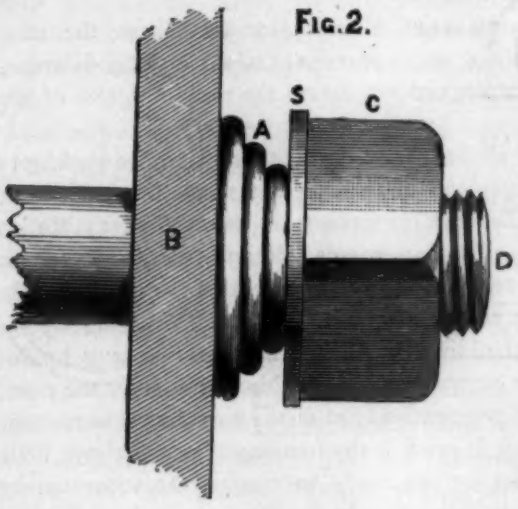
New Nut-Locking Washer.—At a recent meeting of the Institute, the Secretary described the device herewith illustrated, which was presented for exhibition by George H. Ball, Esq., of Mount Holly, N. J. The invention is known as Winslow's Improved Nut-Locking Washer, for fish-plate bolts, railroad trucks, etc., and its features will be apparent from the following description:

FIG. 1

Figure 1 represents a volute conical spring, formed of spring wire, which is placed on the bolt with its base against the fish-plate, followed by a friction washer, and both brought to their places by turning the holding nut up firmly against them, as shown in Figure 2, in

which the nut C, friction-washer S, spring A, and fish-plate B, are shown in position on the bolt D.

FIG. 2.



It is claimed for the device, that the spring, by its considerable resisting force against the holding nut, prevents any loosening of the same, in consequence of the vibration to which it will be exposed when in use. W.

Centennial Exhibition.—As, but a little more than a year now remains before the opening of the Exhibition an increased interest is manifested in the preparations, and a desire to know what progress is being made on the different buildings.

With the view of furnishing information on this subject the following particulars have been obtained from official sources:

The art building is from designs by Mr. H. J. Schwarzmann, and the contract was let to Mr. Dobbins, last summer, to be finished by January 1st, 1876.

At first there was some apprehension in the public mind as to the ability to complete it by that time, owing to the supposed difficulties of obtaining the materials in season, and especially the granite. A large portion of this is now delivered on the ground, and the quantity now at sea and ready for shipment at the quarries warrants the belief that all will be delivered by May 1st.

The brick work of the interior walls has reached a height of about fifty feet, and the setting of the granite is well started. The iron work is being pushed forward in the shops, and all other materials are fully provided for.

The preparations of Mr. Dobbins for setting the stone and iron work (including eight traveling steam cranes, derricks, etc.) have been most ample, and will insure the rapid progress of this portion of the work.

In view of all these facts the contractor is quite confident that he will be able to complete the building before the time specified in his contract. As the work progresses it meets the expectations of those who advocated this particular design, and the favor with which it has been received in foreign countries (where it has been largely published) is very gratifying.

The main building, which will be 1880 feet long by 464 in width, is also under contract to Mr. Dobbins, and, as in the case of the art building, his preparations are of the most ample character.

The ground is graded, the foundation piers (about 700) are nearly all built to the surface ready to receive the superstructure, and the work has been delayed only by the unprecedented severity of the winter. Three railroad tracks have been laid the full length of this building, which will greatly facilitate the delivery of material on the spot.

The iron has been rolled and fitted, and is now ready for delivery on the grounds. The erection will commence as soon as the weather permits, certainly not later than April 1st.

The contract for this building also requires it to be finished by January 1st next, but as the preparations are so well advanced, and as the finishing can be proceeded with in part as soon as a portion of the frame work is up, it is not improbable that it will be completed two months sooner.

The machinery building is from designs by and its erection is in charge of Messrs. Pettit & Wilson, engineers and architects to the Board of Finance. It will consist of five principal avenues, two of 90 feet and three of 60 feet in width, parallel to each other, and crossed with a central transept.

It will be of wood and iron, 1402 feet long by 360 feet wide, with a wing in the rear of the centre 208x210 feet, in which is a water tank 60 by 160 feet for the use of hydraulic machines.

Mr. Philip Quimby, of Wilmington, Del., has contracted to complete this building by October 1st next. He has broken ground, has much material worked out, and will put a large force at work as soon as the weather permits, and from the advanced state of his preparation, it is believed he will complete it by the time agreed on.

The horticultural hall is from the design of Mr. H. J. Schwarzmann, and will be built of iron and glass. It is under contract to Mr. John Rice, to be finished by September 15th, and the committee have full confidence in his completing it by that time.

The agricultural hall will be constructed entirely of wood and glass, and from the ease with which these materials can be obtained, no apprehension is felt in regard to having it ready in ample time.

The water and gas supply, grading and preparation of the grounds, means of transportation to and within the enclosure, railroad tracks in the main building and machinery hall, and all other matters, are receiving their full share of attention.

It will thus be seen that although the work to be done on the spot has been delayed by the severe winter, yet that portion which is to be done elsewhere has been pushed forward with great earnestness, and there need be no apprehension as to both buildings and grounds being ready for the reception of goods by the time fixed.

We shall endeavor to note the progress made from month to month and keep the readers of the JOURNAL informed on the mechanical and engineering matters connected with the great undertaking.

A great feature of the Exhibition will be not only the machines, but the full processes of manufacture, to a much greater extent than any former exhibition. K.

Firemen's Respirators.—Professor Tyndall has recently made considerable improvements in his respirator, which now promises to be of great value to firemen. The apparatus, when in use, is secured to the head of the wearer by two narrow elastic straps, one of which passes from the upper part of the apparatus round the head; the other passes from the lower part of the apparatus round the neck. The total weight when charged with the filtering materials is about nine ounces, and its advantages over previous forms are its lightness, simplicity of construction, and cheapness; the ease and rapidity of adjustment; no undue heating of the head, the face only being covered; no chance of derangement by the bursting of water tubes, etc., as none are used. The supply of air to the mouth and nose being perfectly free, there is therefore no excessive secretion of saliva.

On the alleged Expansion in Volume of various substances in passing by Refrigeration from the state of Liquid Fusion to that of Solidification.—The conclusions of Mr. Mallet upon the "Dilatation of Cast Iron and the Phenomena of the Crane Ladle," published in our February number, have excited so much interest that we republish here, from *Nature*, an abstract from his previous paper before the Royal Society, which has the above title. Mr. Mallet's well-known ability makes his opinion upon these matters of great scientific value.

Since the time of Reaumur it has been stated with very various degrees of evidence, that certain metals expand in volume at or near their points of consolidation from fusion. Bismuth, cast-iron, antimony, silver, copper, and gold are amongst the number, and to these have recently been added certain iron-furnace slags. Considerable physical interest attaches to this subject from the analogy of the alleged facts to the well-known one that water expands between 30° Fahr. and 32°, at which it becomes ice; and a more extended interest has been given to it quite recently by Messrs. Nasmyth and Carpenter having made the supposed facts, more especially those relative to cast-iron and to slags, the foundation of their peculiar theory of lunar volcanic action as developed in their work "The Moon as a Planet, as a World, and a Satellite" (4to, London, 1874). There is considerable ground for believing that bismuth does expand in volume at or near consolidation; but with respect to all the other substances supposed to do likewise, it is the object of this paper to show that the evidence is insufficient, and that with respect to cast-iron and to the basic silicates constituting iron slags, the allegation of their expansion in volume, and therefore their greater density when molten than when solid, is wholly erroneous. The determination of the specific gravity in the liquid state of a body having so high a fusing temperature as cast-iron is attended with many difficulties. By an indirect method, however, and operating upon a sufficiently large scale, the author has been enabled to make the determination with considerable accuracy. A conical vessel of wrought iron of about 2 feet in depth and 1·5 feet diameter of base, and with an open neck of 6 inches in diameter, being formed, was weighed accurately empty, and also when filled with water level to the brim; the weight of its contents in water, reduced to the specific gravity of distilled water at 60° Fahr. was thus obtained. The vessel, being dried, was now filled to the brim with molten grey cast-iron, additions of molten metal being made to maintain the vessel full until it had attained its maximum

temperature (yellow heat in daylight) and maximum capacity. The vessel and its contents of cast-iron when cold were weighed again, and thus the weight of the cast-iron obtained. The capacity of the vessel when at a maximum was calculated by applying to its dimensions at 60° the coefficient of linear dilatation, as given by Laplace and others, to its range of increased temperature; and the weight of distilled water held by the vessel thus expanded was calculated from the weight of its contents when the vessel and water were at 60° Fahr. after applying some small corrections.

We have now the elements necessary for determining the specific gravity of the cast-iron which filled the vessel when in the molten state, having the absolute weights of equal volumes of distilled water at 60° and of molten iron. The mean specific gravity of the cast-iron which filled the vessel was then determined by the usual methods. The final result is that, whereas the specific gravity of the cast-iron when cold is 7·170 it was only 6·650 when in the molten condition; cast-iron, therefore, is less dense in the molten than in the solid state. Nor does it expand in volume at the instant of consolidation, as was conclusively proved by another experiment. Two similar 10-inch spherical shells 1·5 inches in thickness, were heated to nearly the same high temperature in an oven, one being permitted to cool empty as a measure of any permanent dilatation which both might sustain by mere heating and cooling again, a fact well known to occur. The other shell, when at a bright red heat, was filled with molten cast-iron and permitted to cool, its dimensions being taken by accurate instruments at intervals of thirty minutes, until it had returned to the temperature of the atmosphere (53° Fahr.), when, after applying various corrections, rendered necessary by the somewhat complicated conditions of a spherical mass of cast-iron losing heat from its exterior, it was found that the dimensions of the shell whose interior surface was in perfect contact with that of the solid ball which filled it were, within the limit of experimental error, those of the empty shell when that also was cold (53° Fahr.), the proof being conclusive that no expansion in volume of the contents of the shell had taken place, which was further corroborated by the fact that the central portion was found much less dense than the exterior, whereas if the cast-iron expanded in consolidating the central portions must be more dense than the exterior.

It is a fact, notwithstanding what precedes and well known to iron founders, that certain pieces of cold cast-iron do float on molten cast-

iron of the same quality, though they cannot do so through their buoyancy, as various sorts of cast-iron vary in specific gravity at 60° Fahr., from nearly 7·700 down to 6·300, and vary also in dilatability; that thus some cast-irons may float or sink in molten cast-iron of different qualities from themselves through buoyancy or negative buoyancy alone; but where the cold cast-iron floats upon molten cast-iron of less specific gravity than itself, the author shows that some other force, the nature of which yet remains to be investigated, keeps it floating; this the author has provisionally called the repellent force, and has shown that its amount is, *cæteris paribus*, dependent upon the relation that subsists between the volume and "effective" surface of the floating piece. By "effective" surface is meant all such part of the immersed solid as is in a horizontal plane, or can be reduced to one. The repellent force has also relation to the difference in temperature between the solid and the molten metal on which it floats.

The author then extends his experiments to lead, a metal known to contract greatly in solidifying, and with respect to which there is no suggestion that it expands at the moment of consolidation. He finds that pieces of lead having a specific gravity of 11·361 and being at 70° Fahr. float or sink upon molten lead of the same quality, whose calculated specific gravity was 11·07, according to the relation that subsisted between the volume and the "effective" surface of the solid piece, thin pieces with large surface always floating, and *vice versa*. An explanation is offered of the true cause of the ascending and descending currents observed in very large "ladles" of liquid cast-iron, as stated by Messrs. Nasmyth and Carpenter. The facts are shown to be in accordance with those above mentioned, and when rightly interpreted, to be at variance with the views of these authors.

Lastly, the author proceeds to examine the statements made by these authors, as to the floating of lumps of solidified iron-furnace slag upon the same when in a molten state; he examines the condition of the alleged facts, and refers to his own experiments upon the total contraction of such slags, made at Barrow Ironworks, and a full account of which he has given in his paper on the true nature and origin of volcanic heat and energy, printed in Phil. Trans. 1873, as conclusively proving that such slags are not denser in the molten than in the solid state, and that the floating referred to is due to other causes. The author returns thanks to several persons for facilities liberally afforded him in making these experiments.

Editorial Correspondence.

NAVY YARD, WASHINGTON, D. C., Jan. 20, 1875.

Editor Journal Franklin Institute.

DEAR SIR: In your number for March, 1874, you published the record of a curious phenomenon displayed by a piece of iron under test, which exemplified the law of the "Increase of resisting power of metals" by stress. In the May or June number appeared a table with an analysis, embracing a number of similar experiments. The piece of iron whose action furnished the first article, appeared also in the second, viz., No. 1, and at the date of the strain reported, January, 1874, it had reached the limit of elasticity at 28250 lbs.

The specimen was laid aside for nearly one year, until Dec. 20th, 1874, when it was again pulled and broken at a strain of 29350 lbs.

The entire history of the specimen is as follows: It was hammered from old boiler iron, and turned down in the lathe to a cylindrical test piece ·800 of an inch in diameter and 1·5 inches long, was pulled in January, 1874, until the lever fell at the limit of elasticity, 24300 lbs.; weights were then taken off until it rebalanced at 23075 lbs. The piece was rested *seventeen hours* and repulled, when it reached 28250 lbs. before the lever fell, and was rebalanced at 26100 lbs. It was then laid aside for one year, and then broken at 29350 lbs.

Its measurements after the *second* pull were: diameter .677, showing a contraction of area equal to 28·3 per cent. of original diameter, and its length 2·07 inches, showing an increase of 38 per cent. of original length. After breaking, the diameter at the fracture was ·565 inch, showing entire contraction of area of 50·1 per cent., and length after fracture was 2·28, an increase of 52 per cent. in original length.

The point of beginning to stretch, on the final pull, was at 28400 lbs., almost identical with the point of limit of elasticity on the previous pull, one year before, and 96·7 per cent. of the final breaking strain. This point was not measured on the first and second pulls, but judging from the action of other similar pieces since broken, it was at about 70 per cent.

The iron was tough and fibrous, and in this test gave as tensile strength per square inch of original area 48140 lbs., and great ductility. The second day's limit of elasticity was 56190 lbs. per square inch, and the third and last breaking pull gave 58383 lbs., but with the ductility nearly all gone.

L. A. BEARDSLEE,
Commander, U. S. N.

Bibliographical Notices.

CATECHISM OF THE LOCOMOTIVE. By M. N. Forney, Mechanical Engineer, New York, 1875. Published by *The Railroad Gazette*, 73 Broadway:—The author of this book of 650 pages has been long and favorably known as the Engineering Editor of *The Railroad Gazette*. His familiarity with railroad management in America renders him well qualified to instruct on all that pertains to the locomotive. The contents of this book have already appeared in the pages of the *Gazette*, its publication in that manner having extended over a period of more than a year. Its collection into one volume adds a book long wanted to the library of the engineer. Its production in catechetical form seems to have originated in a belief that "it has some very decided advantages in writing for those who have not acquired studious habits of thought," as "to such, the question asked presents first a distinct image of the subject to be considered, so that the explanation or instruction which follows is much more apt to be understood than it would be if no such questions had been asked." To prepare an acceptable work on such a subject as the locomotive in its American aspect requires on the part of the author a degree of familiarity with his subject attainable only in his capacity as a practical mechanical engineer. The subject has been treated in the volume before us with clearness and sufficient fullness for all practical purposes. It is written on what might be called a low plane, well fitted for the understanding of persons of moderate education. The absence of technical terms is very refreshing when we find the language so clear and not encumbered by many useless words. A translation of the German work "Katechismus der Einrichtung und des Betriebs der Locomotiv," by Georg Kisak, would have proved very useful if the translator should adapt its matter to the American form of locomotive. Mr. Forney has given the equivalent of this in the present volume, having used what seemed best for his purpose of the above-mentioned work, and added much that is original. Through all the pages we recognize the mode of thought of one who has been himself a student, not only of books, but of working machinery. To the steam engineer of modern days, the "Steam Indicator" is what the Stethoscope is to the physician. With it he diagnoses the breathing organs of his patient. Familiar as this instrument is to the marine engineer and the builder of stationary engines, its use on locomotives running maybe at forty to fifty miles an hour is not so easy an affair. The description in Mr. Forney's book of the process of using the indicator on locomotives is very clear, and the portion of the book devoted to this subject is in the

highest degree commendable. On page 50 is a very satisfactory illustration of steam expansion, presented in a mechanical manner, in which the card upon which the diagram is drawn is represented as a plane moving in front of the indicator pencil; yet in the illustration of the indicator shown in position on an engine on page 234, the Richards' indicator with the paper on the drum of this instrument is given as the proper method of using this instrument. This will work well at slow speeds, yet we are inclined to the belief that the flat card, as shown on page 47, would prove more serviceable at high speeds. We have seen cards taken in this way from engines making 900 revolutions per minute.

We would call attention to the novel and ingenious illustration of unequal strains on iron plates, as shown by a hole punched in a rubber band, p. 93. This round hole in the band represents a rivet hole; if now across the band two parallel lines be drawn as if directly across the centre of the hole, when the band is stretched these lines will not remain parallel but will separate widest next to the hole, indicating where the fibers of the rubber are stretched the most. The author in this manner shows what may be the case when plates of iron are similarly stretched, a fracture being liable to start next the hole, "after which the plate will be broken, as it were, in detail." An interesting description of the strains in the bent tube of the Bourdon steam gauge has attracted our attention. The portion of the book devoted to the subject of springs as used on locomotives, and the theory of equalization of load in the springs, seems from a foot note to have been, mainly, taken from "Die Schule des Locomotivführers," by Messrs. J. Brosuosc and R. Koch, while the frame work and its arrangement is entirely new, and very clear.

In Part XVI., which treats of screw threads, bolts and nuts, he advocates the standard as adopted by the Franklin Institute, fully illustrating its general principles, and at the same time pointing out the need of intelligent forethought on the part of the workmen who have the care of these tools. He says that in many shops the men who make the taps have only a vague idea that so long as they get the proper number of threads to the inch they are doing all that is necessary to secure uniformity. He urges care on their part to secure the great advantage that should result from uniformity of standard screws and threads. It is impossible for us to allude in detail to all the subjects treated in this book, but we commend it not only to practical mechanics but to the general reader. We cannot help regretting that the mechanical execution of the book is not of a higher order. It is illustrated by 250 engravings and twenty full-page plates of various styles of locomotives. Many of the cuts are white lines on a black ground. These heavy masses of black are always difficult to print, but the greater part of those in this volume bear unmistakable indications of inexcusable carelessness on the part of the printer.

The black cuts look as if a very old dry inking roller had been used. The type is good, and all the pages have been well "made ready," showing care in this direction. The paper is good, and extra calendered, and has been printed dry, but the ink has bad drying properties and "sets off" on the opposite pages, as well as smudges when touched with the finger. The matter is indeed worthy of much finer work in printing. Any one familiar with the illustrated books published in France, must have noticed the perfection of the color shown in the masses of black in the cuts of the character used in this book. Some experiments which we have seen conducted in the printing houses of this city seem to indicate that when broad masses of black with light lines are required, they should be printed on damp paper, with good new inking rollers and a fine quality of ink. Familiar as we have been with the subject matter of the Catechism as it appeared week after week in the *Gazette*, yet the collection as now presented reads almost as a new composition, and is indeed a valuable contribution to the literature of the workshop. S.

Franklin Institute.

HALL OF THE INSTITUTE, Feb. 17th, 1875.

The stated monthly meeting was called to order at 8 o'clock P.M., the President, R. E. Rogers, in the chair.

The minutes of the stated meeting of January were read and approved.

The Actuary submitted the minutes of the Board of Managers and of the several Standing Committees, and reported the following from the proceedings of the Board at their meeting held February 10th, 1875.

To the Board of Managers of the Franklin Institute:

GENTLEMEN: At a meeting of the Committee on Sciences and the Arts, held January 18th, 1875, it was

Resolved, That the award of the Elliott Cresson Gold Medal to Joseph Zentmayer, for many and great improvements in the construction of microscopes, object glasses and accessories, be recommended to the Board of Managers of the Institute.

Respectfully, JNO. C. CRESSON, *Chairman.*

On motion, it was

Resolved, That the Elliott Cresson Gold Medal be awarded to Joseph Zentmayer, in accordance with the recommendation of the Committee on Science and the Arts.

The Actuary also reported the following donations to the Library, received from Jan. 23d to Feb. 10th, 1875:

Annales des Ponts et Chaussées, for October and November, 1874. From the Editor.

Monthly Notices of the Royal Astronomical Society, Vol. 35, No. 2, December, 1874. From the Society.

Informe al Supremo Gubierno del Peru sobre una Expedicion al Interior de la Republica, por John W. Nystrom. From the Author.

Verhandlungen des Naturhistorisch-Medicinischen Vereins zu Heidelberg, 1874. From the Society.

Jahrbuch der K. K. Geologischen Reichsanstalt, for July, August, September, 1874, Vol. 24. From the Society.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale, for December, 1874. Paris. From the Society.

Chief Engineer's Monthly Report of the Manchester Steam-Users' Association for the Prevention of Steam Boiler Explosions, for November, 1874. Manchester. From the Association.

Mr. Bullock, from the Library Committee, reported that the Board of Managers has made an appropriation of $5000 for the purchase of books for the Library. A considerable number of books have already been purchased, and others ordered, and the entire amount will be expended as rapidly as the proper selections can be made.

At the request of the Secretary, Mr. Zentmayer then gave an interesting account of the progress of the improvements in microscopic lenses, and of the difficulties to be overcome in those for the solar or gas microscope, to obtain a perfectly flat field on the screen, and illustrated his late improvements by using alternately lenses of his own make and those of the best French makers, to throw images on the screen with the oxy-hydrogen light.

The Secretary then described, with the aid of the lantern, an improved life raft and rails for ships, the invention of Mr. R. W. Newbury, New York. This invention consists of two hollow cylinders of sheet metal, about 8 inches in diameter and 10 or 12 feet long, having conical ends, held in a position parallel to each other,

and three or four feet apart, by four bars of metal or wood. Across the whole is stretched woven wire or netting.

The raft is supported on edge at the side of the ship's deck by iron stanchions, and fastened in such a manner that it is easily detached when required, thus forming a necessary portion of the ship under ordinary circumstances, and a means of saving life in case of disaster.

Also an improved knife for druggists' use in cutting dried herbs, and also for cutting tobacco, the invention of Jno. G. Baker, the peculiarity of which consists in so connecting the blade to the lever, that in descending the blade is held parallel with the base of the instrument, and at the same time has a horizontal motion, thus giving it a sliding motion through the substances to be cut.

Under the head of new business Mr. C. Chabot offered the following:

"*Resolved*, That a committee be appointed to review, and, if necessary, revise, the By-Laws and Rules, and report to the Institute as early as practicable; the committee to consist of nine members, not more than four being chosen from the Board of Managers. The President will be aided in his choice by nominations."

Mr. Close remarked that he could see no reason for dictating regarding the number of Managers to be placed on such a Committee; that the Managers did not claim to know more of such matters than other members of the Institute, nor should they be debarred the privileges nor exempt from the duties of other members by reason of their being on the Board. He moved that the portions of the resolution relating to the Managers be struck out, which was accepted by the mover.

Mr. Wm. P. Tatham asked the mover to state some reason why such a committee should be raised, stating that he knew of no reasons for or against.

Mr. Chabot replied that it was generally believed that some changes in the By-Laws were desirable, and as the last edition printed is exhausted it would be better to make such amendments as are wanted before printing a new edition.

Mr. Close remarked that the mode of amending the By-Laws was clearly laid down, and if any changes were desirable let them be stated and presented to just such a meeting as this.

Mr. Sellers said that the effect of passing this resolution would be to open a long and unpleasant discussion, and he hoped he might

not be placed on such a committee, as he was heartily tired of tinkering with By-Laws.

On putting the Resolution it was lost.

Mr. Tatham called attention to the fact that the election of one of the Vice-Presidents, Dr. Rogers, to the Presidency left a vacancy in that office, and moved that the Institute go into an election for a Vice-President to fill this vacancy, which was adopted.

Mr. Bloomfield H. Moore was the only one placed in nomination.

The Chair appointed Mr. Chas. Bullock and Chas. S. Close as tellers.

All the votes cast were for Mr. B. H. Moore, who was declared elected.

The President then announced the standing committees of the Institute for the current year as follows:

On Library.—Chas. Bullock, Saml. Sartain, Wm. P. Tatham, Jos. M. Wilson, Geo. F. Barker, Coleman Sellers, J. B. Knight, B. H. Moore, J. W. Nystrom, Isaac Norris, Jr.

On Minerals.—F. A. Smith, Theo. D. Rand, Saml. B. Howell, Clarence Bement, Wm. H. Wahl, E. J. Houston, John C. Trautwine, Robt. Grimshaw, Edward F. Moody, Jos. M. Wilson.

On Meteorology.—Pliny E. Chase, Hector Orr, Isaac Norris, Jr., John Wise, J. E. Mitchell, Thos. S. Speakman, Jas. A. Kirkpatrick, David Brooks, A. Purves, Wm. H. Wahl.

On Models.—Wm. B. Bement, Edward Brown, Theo. Bergner, John Goehring, L. L. Cheney, Edwin Smith, C. Chabot, J. B. Knight, S. Lloyd Wiegand, D. S. Holman.

On Arts and Manufactures.—A. B. Barry, Geo. V. Cresson, Hector Orr, Coleman Sellers, Jr., W. B. LeVan, S. M. Ward, M.D., H. W. Bartol, J. Sellers Bancroft, Alfred Mellor, Cyrus Chambers, Jr.

On Meetings.—J. B. Knight, B. H. Moore, Saml. Sartain, Washington Jones, Geo. F. Barker, Henry Cartwright, Chas. S. Close, Wm. P. Tatham, J. Sellers Bancroft.

The President announced that hereafter the rule requiring the janitor to take the names of members on entering the meetings, would be enforced.

The Secretary stated that as yet but few of the copies of the exercises to commemorate the 50th anniversary of the foundation of the Institute, held in February, 1874, had been taken, and recommended members to buy them.

Mr. Weaver asked what is to become of the amendments to the by-laws proposed by Mr. LeVan at the last stated meeting.

The President stated that they not having been advertised as required by Article 16, they could not be acted on to-night.

Mr. Eldridge did not agree with the chair, because were that the case it would be possible for the officer whose duty it is to advertise them, to defeat action during the entire term of his office, on any amendment to which he was opposed, simply by neglecting or refusing to advertise it.

The Secretary stated that he had been requested by the mover of the amendments not to advertise them, as he (Mr. LeVan) had determined to withdraw them at this meeting, and that he was quite certain the seconder would consent to the withdrawal; that he (the Secretary) had taken counsel with several members, and becoming satisfied that he was justified in the omission, did not advertise them.

The chair decided that the rule requiring the advertisement of the proposed amendments not having been complied with, they will be considered to-night and acted on at the next stated meeting.

In reply to a question whether or not he intended to withdraw the proposed amendments, Mr. LeVan stated that he had intended doing so, but the seconder objected, and now he intended pressing them.

In reply to a question of Mr. Tatham, he further stated that his reason for urging the first amendment was that many members are engaged at their usual occupation until 6 P. M., and cannot get to the Institute before 8 o'clock, and his reason for desiring the second amendment was that he thought it would be better to have more fresh members in the Board of Managers, and he therefore renewed his proposed amendments.

Mr. Close moved that the matter be postponed until after some copies of the by-laws are printed, so that members can act more intelligently.

Mr. Tatham said that if they can be postponed at all, they can be postponed indefinitely, and moved that they be indefinitely postponed.

The chair decided that as the by-laws required that proposed amendments be acted on at the next stated meeting after they are offered, a motion to postpone beyond that time is not in order.

On motion, the meeting then adjourned.

J. B. KNIGHT, *Secretary.*

Civil and Mechanical Engineering.

ON SPIRAL WHEELS.*

By Professor L. G. Franck, of the University of Pennsylvania.

The recent exhibition of the Franklin Institute in Philadelphia presented, among other interesting contrivances for transmission of motion, a number of spiral wheels of various constructions. The peculiarities of the properties of some of these wheels induced me to attempt to comprehend all varieties under one head; in other words, to derive some formulæ that express their axial position, as well as the tangential direction of two spirals in contact, and also the velocity of the sliding motion of teeth.

(1). Let A and B be two thin rectangular plates of flexible material—which I shall call for brevity's sake, planes—upon which right parallel lines are drawn equally distant from each other (Figs. 1, 2), $Bq = At$, whose angles at L A C and N B D may be equal or unequal to each other. Let the angle N B D $= \beta$ and L A C $= \alpha$. If these

* Reauleaux' work was consulted in the preparation of this article.

planes are regarded as the developments of circular cylinders, we may, after we have placed B upon A so that M N and K L coincide, curve them back to their original cylindrical shape, leaving the element at A and B in contact. The right lines on the planes will then become screw lines or spirals, as they are sometimes termed. The planes G E and H F will form a certain angle, depending on the obliquity of the lines K L and M N (Figs. 1 and 2), to be denoted by γ, and which is for geometrical reasons equal to the angle D S C (Fig. 3), formed by two planes perpendicular to the plane of the

paper. The line of contact will form the tangent to the spiral at A and B respectively. The angles that the lines S C and S D make with the tangent retain their relative value, as regards the horizontal projection, and are therefore equal to α and β respectively (Fig. 3). Considering these cylinders as the pitch cylinders and the lines upon them as pitch lines, we are enabled to derive equations of condition that belong to spiral wheels of all varieties. From Fig. 3 it is evident that

$$\beta + \gamma + \alpha = 180^\circ \qquad (1)$$

Further, as we have assumed the distances between the parallel lines on both planes to be equal (Fig. 1 and 2), we have

$$A\,t = A\,s.\ \sin\alpha, \text{ and } B\,q = B\,s.\ \sin\beta.$$

Hence, $A\,s.\ \sin\alpha = B\,s.\ \sin\beta$; but as $A\,s$ and $B\,s$ will form the pitch on the cylinders (Fig. 3), we find, introducing the known formula for the pitch, the subsequent expression:

$$\frac{2\pi a}{N_a}\ \sin\alpha = \frac{2\pi b}{N_b}\ \sin\beta;$$

where a and b denote the radii of the wheels A and B, and N_a and N_b their respective number of teeth.

From the above equation we get the ratio:

$$\frac{N_a}{N_b} = \frac{a \sin \alpha}{b \sin \beta} \qquad (2)$$

but as $a \sin \alpha = R\,Q$, and $b \sin \beta = T\,U$; we find also (Fig. 3),

$$\frac{N_a}{N_b} = \frac{R\,Q}{T\,U}. \qquad (3)$$

It appears from these expressions that the numbers of teeth of two spiral wheels in contact are not in direct proportion to the radii; but are as the perpendiculars to the tangent, that is as R Q is to T U. If, further, the velocities of a point on the cylinders A and B are V_a and V_b, we obtain the velocity of sliding motion of a point along two teeth, when we resolve these velocities into components in the direction of the tangent and perpendicular to it.

Let S F and S H (Fig. 4), be equal to V_a and V_b, the respective velocities; S R, S G and S Q and Q H the components. The velocity of sliding motion is then U = S R + S Q; hence

$$U = C \cot g\, \alpha + C \cot g\, \beta = C (\cot g\, \alpha + \cot g\, \beta). \qquad (4)$$

In accordance with the doctrine of maximum and minimum, U becomes a minimum when α is put equal to β.

It appears, then, in order to get a minimum velocity of sliding motion, we must put $\alpha = \beta$. As velocity is one of the factors in the

formula of mechanical effect of friction that increases friction, it is obvious that to diminish friction we must decrease the velocity of sliding friction.

(2). The following examples will explain the use of the derived formulæ:

Example 1. Required the respective radii, a and b, of two spiral wheels; also the pitch of each, and the sliding velocity at the flanks of two teeth in contact.

Given, the number of teeth $N_a = 40$, and $N_b = 20$; the normal axial distance $a + b = 10$ inches; the axial angle $\gamma = 40°$, and one of the tangential angles, $\beta = 60°$.

To find the other tangential angle, we have (formula 1)

$$\alpha = 180 - (40 + 60) = 80°.$$

To find the radii, b and a, we have, $a + b = 10$, and, from formula 2, we have,

$$\frac{b}{a} = \frac{N_b \sin \alpha}{N_a \sin \beta} = \frac{1}{2} \cdot \frac{\sin 80°}{\sin 60°} = 0{\cdot}5686.$$

Hence, $a = \frac{10}{1{\cdot}5686} = 6{\cdot}375$ in., and $b = 10 - 6{\cdot}375 = 3{\cdot}625$ in.

To find the pitch, p_a, of wheel A.

This, for the normal division, is

$$N = p_b \sin \beta = \frac{2\pi b \sin \beta}{N_b} = \frac{2\pi 3{\cdot}625 \times 0{\cdot}866}{20}.$$

$$p_b = \frac{2\pi\ 3{\cdot}625}{20} = 1{\cdot}138 \text{ inches, and } p_a = \frac{2\pi\ 6{\cdot}375}{40} = 1{\cdot}001 \text{ inches.}$$

To find the velocity of sliding motion:

$$U = C(\text{cotg } 60° + \text{cotg } 80°) = 0{\cdot}7537\ C.$$

Example 2. If the given values of Example 1 remain, with the exception that we make $\alpha = \beta$, in order to get a minimum sliding motion, what will be the above required quantities?

To find the tangential angles: $2\alpha = 180 - 40$. Hence, $\alpha = \beta = 70°$.

To find the radii, a and b:

$$\frac{b}{a} = \frac{N_b}{N_a} = \frac{20}{40} = \frac{1}{2}, \text{ and } a + b = 10.$$

$$\text{Hence, } b = \frac{10}{3} \text{ inches; } \quad a = \frac{20}{3} \text{ inches.}$$

The pitch will be $p_a = p_b = 1{\cdot}047$ inches, and the sliding velocity, $U = 2 \text{ cotg } 70\ C = 0{\cdot}728\ C$.

From this we see that the wheels of Example 2 will mechanically be more perfect than the first set on account of the less sliding velocity. The calculation is also less complex, as $a = 2b$, and the pitch is the same for each.

Example 3. Let all quantities remain that are given in Example 1, except make the tangential angle $\alpha = 90°$. Required the radii, pitch, and sliding velocity.

To find the tangential angle, $\beta = 180 - (90 + 40) = 50°$.

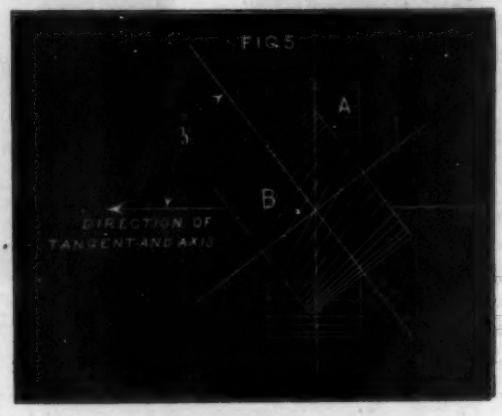
To find the radii, we have

$$\frac{b}{a} = \frac{1}{2} \cdot \frac{\sin 90}{\sin 50} = 0{\cdot}6525, \text{ and } b + a = 10.$$

Hence, $a = 6{\cdot}051$, and $b = 3\ 949$ inches.

To find the pitch of both wheels:

Pitch of $A = p_a = \dfrac{\text{normal division}}{\sin\ 90°}$. It follows, then, that $p_a =$ normal division, which indicates that wheel A becomes an ordinary spur wheel, (Fig. 5.)



$$p_a = \frac{2\pi a}{N_a} = 0{\cdot}95\ ;\ p_b = \frac{2\pi b}{N_b \sin 50} = \frac{1{\cdot}239}{\sin 50°} = 1{\cdot}617 \text{ inches.}$$

To find the velocity of sliding motion:

$U = C(\text{cotg } 50 + \text{cotg } 90) = 0{\cdot}8391\ C$, a quantity which is greater

than the one found in Example 2, indicating a less perfect mechanical contrivance compared with that in Example 2. This contrivance, however, has the advantage that one of the wheels becomes a spur wheel.

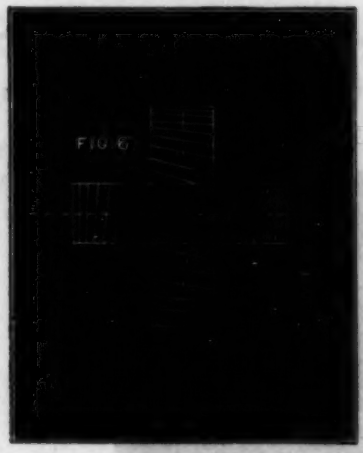
Example 4. Given $N_a = N_b$; $\alpha = \beta$, and the axial angle $\gamma = 90°$. Required the radii, pitch, and sliding velocity.

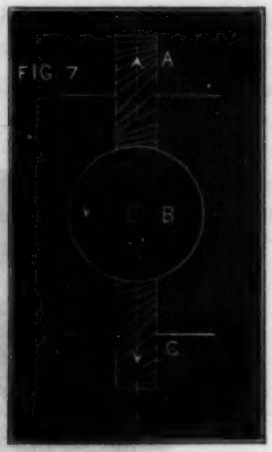
To find the tangential angles, $2\alpha = 180 - 90$. Hence, $\alpha = \beta = 45°$.

To find the radii: $\frac{a}{b} = \frac{\sin 45}{\sin 45}$. From this it follows $p_a = p_b$. $a+b = 10$. Hence, $a = 5$, and $b = 5$ inches.

To find the sliding motion: $U = C(\text{cotg } 45 + \text{cotg } 45) = 2\,C$.

It appears then that, under the above assumptions, both wheels become equal to each other in size, and that both become either right or left handed spirals, (Fig. 6.)





Another remarkable case is, that if B is made a driver working the two followers, A and C, arranged as Fig. 7 exhibits, both followers will move in contrary directions, indicated by the arrows, Fig. 7. That is similar to a set of bevel wheels, and different from that of spur wheels, provided the above three wheels have all right or left handed spiral teeth.

Example 5. If we make the axial angle $\gamma = 0$, then both axes of the wheels become parallel. Given $\alpha = \beta$, $N_a = N_b = 40$, and $a+b = 10$. Required the radii, pitch, and sliding motion.

It is in general, $\alpha+\beta=180$. Hence $\alpha=180-\beta$.

This points out, as the sum of both angles is equal to 180°, that both wheels become spur wheels with spiral threads, of which one must have a left handed spiral, while the other must have a right handed one, (Fig. 8.)

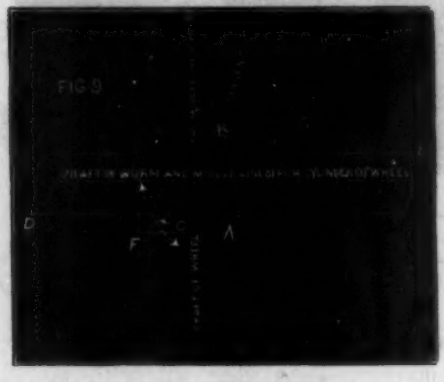
From the above assumption we further get $\alpha=\beta=90°$, which makes both wheels of equal size; $a=b=5$ inches.

$$p_a=p_b=\frac{2\pi 5}{40}=0{\cdot}7852=\text{pitch.}$$

$$U=(\text{cotg } 90°+\text{cotg } 90°)C=0.$$

From the fact that in formula (1) any two of the three angles may be assumed, it is obvious that a great variety of wheels that work together can be constructed. The last assumption gives two spur wheels with straight teeth, and, therefore, the lateral sliding motion equals zero.

(3). Another contrivance that deserves to be taken notice of, is the wheel and worm or endless screw. The worm consists of a cylinder, and thread continuously wound around it. The tangent drawn to the thread gives the obliquity of the teeth of the wheel.



Let F G (Fig. 9) be the developed pitch cylind r of the worm, and D E that of the wheel. If we denote by $p_a=AC$, the pitch of the

worm, which is here a portion of an element of the cylinder, and therefore a straight line, we find for the angle of inclination:

$$\text{Tang A B C} = \frac{\text{A C}}{\text{A B}} = \frac{p_b}{2\pi b} = \text{tang } \beta.$$

Hence the pitch of screw and wheel:

$$p_b = 2\pi b \text{ tang } \beta = p_a = \frac{2\pi a}{N_a}$$

provided the axial angle $\gamma = 90°$.

We have also $\frac{N_a}{N_b} = \frac{n_b}{n_a}$, where n_b and n_a are the revolutions of the worm and wheel respectively. Commonly but one tooth is taken for the worm; therefore $N_b = 1$, which gives $N_a = \frac{n_b}{n_a}$ Further $\alpha + \beta + 90 = 180$, and $a + b = m$, which expressions enable us to get other required quantities. An ordinary spur wheel may be driven by a worm, a statement that has already been made in connection with Fig. 5, if the axis of the worm is turned just about the angle β (Fig. 10) from its former position (Fig. 9). It is, however, required to

make now the pitch of the wheel, as A C stands oblique to the face of the wheel, $\frac{p_a}{\cos \beta}$, where p_a denotes the former pitch of the wheel.

(4). The friction between worm and wheel is considerable. It is therefore of importance to know what ratio with regard to the radius of the worm and to its pitch should be employed in order to diminish friction.

Applying the well known formula derived in mechanics,

$$\frac{P_1}{P}=\frac{1+f.\frac{2\pi b}{p_b}}{1-f.\frac{p_b}{2\pi b}}, \text{ where P denotes the force}$$

tangent at the circumference of the pitch circle of the worm to overcome the resistance and friction, while P is the force required to overcome the resistance only; we find, introducing for the coefficient of friction, $f = 0{\cdot}16$, the subsequent formula of approximation:

$$\frac{P_1}{P}=1+\frac{b}{p_b}, \text{ where b denotes the radius of}$$

the worm, and p_b the pitch. It is evident, in order to gain useful effect, that we must give $\frac{b}{p_b}$ its least value. Morin recommends $b = 3p_b$; Redtenbacher, $b = 1{\cdot}6p_b$, and Reauleaux gives as a rule $b = p_b$, which, as we will see, give a great difference in the final result. If we substitute the above values, we find:

$$P_1 = 4P;\ P_1 = 2{\cdot}6P, \text{ and } P_1 = 2P.$$

Reauleaux' rule gives, under ordinary circumstances, a very small cylinder. If, however, we apply his formula, we shall still have a loss of 50 per cent. of useful effect.

(5). Some other varieties are well worth remarking. If we make in the fundamental formula $a+b=m$; $a=b=\infty$, we obtain two racks, one of which may be made the driver and the other the follower. Let A and B (Fig. 10) be two racks of which the parallel lines

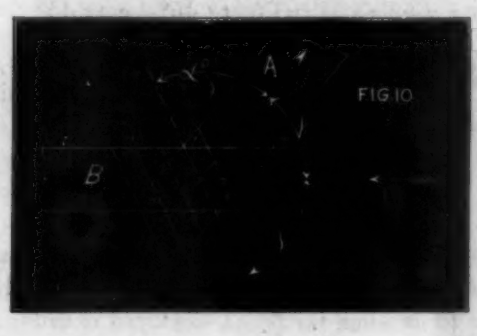


FIG 10

of both have equal normal distances. We have the algebraic sum of

α, γ and $\beta = 180°$, and the velocity for sliding motion: $U = (\text{cotg}\ \alpha + \text{cotg}\ \beta)C$.

Example. Given the axial angle $\gamma = 90$, and $\alpha = \beta$; further, $a = b = \infty$. To find the velocity of each rack (Fig. 11).

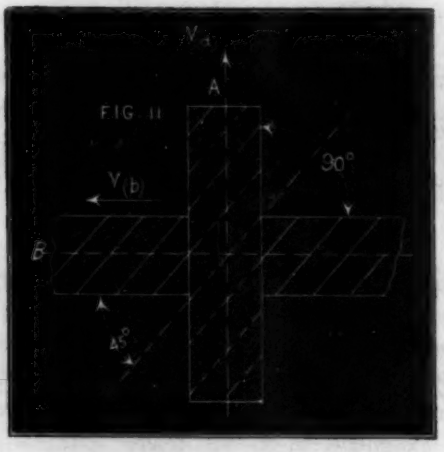
It is $\gamma + \beta + \alpha = 180°$. Therefore, $90 + 2\alpha = 180$. Hence $\alpha = \beta = 45°$.

From Fig. 4 we have, $C = V_a \sin \alpha$, and

$$C = V_b \sin \beta.$$

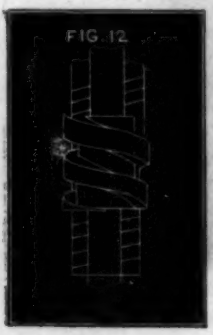
Whence
$$\frac{V_a}{V_b} = \frac{\sin \beta}{\sin \alpha} = \frac{\sin 45°}{\sin 45°} = 1.$$

Hence, $V_a = V_b$.



The relative velocity of sliding motion is

$$U = C(\text{cotg}\ \alpha + \text{cotg}\ \beta) = C(\text{cotg}\ 45° + \text{cotg}\ 45°) = 2\,C.$$



(6). If a rack is worked (Fig. 12) by a screw-wheel we have, when the tangential angle of the teeth of the rack is α, and the axial angle equal to γ, the tangential angle of the wheel $\beta = 180 - (\alpha + \gamma)$, while the velocity of sliding motion along the tooth is again $= C(\text{cotg}\ \alpha + \text{cotg}\ \beta)$. It is easily to be seen that in the preceding cases a considerable lateral pressure is produced.

If the obliquity of the teeth of the rack, upon

which the value of the lateral pressure depends, is arranged so that

it is just balanced by the sliding friction that acts in the opposite direction, the rack (Fig. 13) moves in its ascribed path, mathematically speaking, without guides. This principle was ingeniously applied, first to my knowledge, by Messrs. W. Sellers & Co.

AN ACCOUNT OF SOME EXPERIMENTS MADE AT MULHOUSE, BY MONS. BURNAT, ON THE EFFICIENCY OF SEVERAL KINDS OF COATING IN PREVENTING THE LOSS OF HEAT BY RADIATION FROM THE SURFACES OF STEAM-PIPES.

By Chief Engineer B. F. Isherwood, U. S. Navy.

During the session of "La Société Industrielle de Mulhouse," Elsass, on the 26th of January, 1859, there was read the report made by Mons. E. Burnat for the Commission charged, among other matters, with the examination of the plastic composition or mortar proposed as a coating by Mons. Pimont for the prevention of heat-radiation from the surfaces of steam-pipes, hot water-pipes, etc. As very few experiments appear to have been made on this subject, though one of the highest industrial importance, and as these of Mons. Burnat have never been published in English, I have selected all the observed data given in the above named report, converted it from French into British measures, and, arranging it in my own way, have made the calculations and drawn the conclusions necessary to render the results of use to the practical engineer. I wish distinctly to here state that I have taken nothing from the report except the observed data; indeed, it contains nothing else to take.

The experimental apparatus was as follows: five groups, each consisting of four cast iron pipes of 4·7245 inches external diameter, and

exposing an aggregate surface of 58·4717 square feet per group, were arranged parallel to each other with intervening spaces of 39⅜ inches. The thickness of the metal of the pipe was 0·25 inch. The groups were inclined 0·05 in 1·00, and the highest point of each was connected with a steam-pipe supplied from the same boiler, while the lowest point was connected with a tank properly constructed and arranged for the reception of the water resulting from the condensation of the steam. Four of the groups were covered with the different non-conducting substances proposed, and the fifth was left uncovered or bare to furnish the base of comparison. The apparatus was placed in a large unheated hall, free from air currents; and the condensation of the steam within the pipes was wholly due to the difference between the temperature of that steam and the temperature of the air surrounding them. By this system, the trials of the efficiency of the different non-conducting substances were made simultaneously and under identical conditions, the same steam-pressure existing within the pipes of each group, and the same air-temperature surrounding them. For facility of reference, the groups have been numbered from 1 to 5, in the following Tables, Nos. 1 and 2 containing the data and results of the experiments.

The non-conducting substances with which the pipes of each group were surrounded were as follows (Table No. 2):

1*st Group.* The pipes of this group were first covered with common straw to the thickness of six-tenths of an inch, laid lengthwise; and around this wisps or tresses of the same straw were wound spirally and close together.

2*d. Group.* The pipes of this group were left bare, and exposed to the air their cast iron surfaces in the state in which they left the mould.

3*d Group.* The pipes of this group were enclosed in hollow tiles or pipes of pottery, whose inner diameter was greater than the outer diameter of the steam-pipes, whereby an annular air-space was left between the pottery and iron surfaces. The pottery-pipes were held in place by iron wire, and coated with a mixture of loamy earth and chopped straw, which, in its turn, was covered with tresses of common straw.

4*th Group.* The pipes of this group were covered with cotton waste to the thickness of one inch, held in position by wrapping cloth fastened with strings.

5th Group. The pipes of this group were coated with a plaster composition furnished by Mons. Pimont, consisting essentially of clay kneaded in water and mixed with cows' hair, and perhaps other substances. Its application to the surface of a pipe was begun, by the help of netting, with a coating of variable thickness, along which laths were placed nearly touching, and held in position by twine. On these another coating of the plaster was spread, and then laths again, and so on, until an aggregate thickness of 2·3622 inches was built up. The total number of experiments made with this substance was twelve, in nine of which (5th group) the plaster was left with its natural dark brown or mud color, and in three of which (5th group *bis*) its surface was painted white, with a view to ascertain whether its non-conducting efficiency was affected by color.

Finally, with the pipes of the second group, two trials (2d group *bis*) were made of the non-conducting efficiency of some old felt which had been treated with caoutchouc and used on machines for printing textile fabrics. The thickness of this coating is not given.

Before proceeding to experiment with the non-conducting substances above described, eleven trials were made with the apparatus in its bare state, none of the pipes being covered, to ascertain whether each group under identical conditions of steam-temperature and air-temperature, would condense the same weight of steam in the same time. The results will be found in Table No. 1, under the numbers of the different groups, expressed relatively. The greatest discrepancy for any one experiment is 5·9 per centum; but the mean of the eleven experiments gives, for the different groups, 2·3 per centum as the maximum discrepancy. Calling the weight of steam condensed in a given time by the pipes of the 5th group, 100·0; then, the weight of steam condensed in the same time by the pipes of the 4th group, will be expressed by 101·4; by the pipes of the 3d group, 101·0; by the pipes of the 2d group, 102·3; and by those of the 1st group, 101·0. The mean results have, therefore, a possible error of 2·3 per centum.

The experiments were made with absolute steam-pressures varying from $1\frac{1}{3}$ atmospheres, or 16·523 pounds per square inch above zero, to two atmospheres or 29·375 pounds per square inch above zero. The pressures were from observation, and I have placed opposite to them in each case the corresponding temperature according to Regnault. The air-temperatures were from observation, and varied between 27 and 47 degrees Fahrenheit.

The objections to the experiments are their fewness, their shortness, and the narrow limits of temperature within which they were made. The substances tried were also too few, and, in some cases, their thickness was not ascertained. The results, exceedingly valuable notwithstanding, will be found, together with the data, in the Tables herewith given, numbered respectively 1, 2, and 3.

The condensation of the steam in the steam-pipes is due wholly to the difference between the temperature of that steam and the temperature of the air surrounding the pipes; and though the discrepancies are numerous and the range of temperature restricted, yet the general result of all the experiments shows the condensation to be in the direct ratio of the difference of the above mentioned temperatures; that is to say, with a difference of one hundred degrees the condensation is twice as great as with a difference of fifty degrees. We can, therefore, depend upon the mean condensation as belonging to the mean difference of temperature, and establish constants from them for the several cases.

Taking first, the bare or uncovered steam-pipes, we find that for them the mean of the results in Table No. 1, and in the column headed "2d Group" in Table No. 2, having regard to the quantity of surface in use in both Tables, is a difference of temperature of 193·21 degrees Fahrenheit, and a corresponding condensation per hour per square foot of surface of 0·584413009 pound weight of steam of the absolute pressure of 22·031 pounds per square inch. Hence for one degree Fahrenheit difference of temperature, cast iron in the natural state and 0·25 inch thick, will condense by exposure in still air 0·00302422672 pound weight of steam of the absolute pressure of 22·031 pounds per square inch per hour per square foot of heat radiating surface. This is equivalent to a heat radiation per hour of 2·874757336690 Fahrenheit units from a square foot of cast iron in its natural state and 0·25 inch thick, for a difference of temperature of one degree Fahrenheit on the opposite sides. These are very valuable constants, and will be found of great use for many purposes in engineering.

The Fahrenheit unit of heat referred to, is the quantity of heat required to raise the temperature of one pound of water at the freezing point and under the atmospheric pressure, one degree Fahrenheit.

TABLE No. 1.—Containing the Data and Results of The Experiments made to Ascertain the Quantity of Heat Radiated from Bare Cast Iron Steam Pipes, under the Experimental Conditions. Outside Diameter of Pipes 4·7245 Inches, Thickness of Metal 0·25 Inch, Radiating Surface of each Group of Pipes 58·4717 Sq. Ft.

Duration of the Experiments in minutes.	Steam-Pressure in the Pipes in pounds per square inch above zero.	Temperatures, in Degrees Fahrenheit.			Weight of Steam Condensed per Hour, per Square Foot of the Heat-Radiating Surface of the Steam Pipes; Expressed Proportionally for the Different Groups of Pipes.					Pounds weight of Steam condensed per hour per square foot of the Heat-Radiating Surface of the Steam-Pipes.
		Of the steam in the pipes.	Of the air surrounding the steam-pipes.	Difference of the two preceding columns.	First Group.	Second Group.	Third Group.	Fourth Group.	Fifth Group.	
52	16·523	217·96	46·85	171·11	102·0	106·0	101·0	102·0	100·0	0·499759
56	16·523	217·96	39·20	178·76	98·8	99·9	99·2	100·8	100·0	0·501807
51	18·359	223·42	44·60	178·82	98·3	100·2	98·3	100·8	100·0	0·534578
56	18·359	223·42	39·65	183·77	102·4	102·8	101·4	102·1	100·0	0·585783
54	18·359	223·42	33·80	189·62	102·6	103·4	101·9	100·0	100·0	0·561205
40	22·031	233·17	40·10	193·07	100·5	101·1	99·0	101·4	100·0	0·602169
58	22·031	233·17	39·65	193·52	102·9	102·8	102·3	101·3	100·0	0·600121
55	25·703	241·60	42·35	199·25	103·2	105·9	104·5	104·5	100·0	0·649277
52	25·703	241·60	41·00	200·60	100·7	102·4	101·3	101·0	100·0	0·634940
53	29·375	249·05	46·85	202·20	102·3	102·6	101·9	100·6	100·0	0·657470
56	29·375	249·05	39·65	209·40	97·0	98·0	100·6	100·6	100·0	0·632892
Means	22·031	233·17	41·24	190·93	101·0	102·3	101·0	101·4	100·0	0·587273

TABLE No. 2, CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE TO ASCERTAIN THE QUANTITY OF HEAT RADIATED FROM CAST IRON STEAM PIPES, UNDER THE EXPERIMENTAL CONDITIONS: WHEN BARE AND WHEN COVERED WITH THE DIFFERENT COATINGS DESCRIBED BELOW. OUTSIDE DIAMETER OF PIPES, 4·7245 INCHES; THICKNESS OF METAL, 0·25 INCH; RADIATING SURFACE OF EACH GROUP OF PIPES, 58·4717 SQUARE FEET.

Duration of the Experiments in minutes.	Steam pressure in the pipes in pounds per sq. inch above zero	Temperatures in degrees Fahrenheit.			Pounds weight of Steam condensed per hour, per square foot of the heat radiating surface of the steam pipes.						
		Of the steam in the pipes.	Of the air surrounding the steam pipes.	Difference of the two preceding columns.	Straw in tresses, wrapped around the steam pipes.	Bare steam pipes. (No covering of any kind.)	Pottery Pipes wrapped with straw, placed around the Steam pipes, leaving an air space between.	Steam pipes covered with cotton waste one inch thick wrapped with packing cloth and secured by strings.	Steam pipes covered with plaster 2·3622 inches thick. Plaster of the natural dark brown color.	Steam pipes covered with plaster 2·3622 inches thick. Plaster painted white.	Steam pipes covered with old felt treated with caoutchouc.
					1st Group.	2d Group.	3d Group.	4th Group.	5th Group.	5th Group bis.	2d Group bis.
60	16·523	217·96	46·40	171·56	0·139277	0·495663	0·170000	0·217108	0·253975	.....	.....
64	16·523	217·96	33·80	184·16	0·151566	0·485422	0·165904	0·204819	0·262169	.....	.....
62	18·359	223·42	33·70	189·72	0·163855	0·555060	0·186386	0·229400	0·286747	.....	.....
58	18·359	223·42	27·05	196·37	0·182289	0·571446	0·264217	0·286747	0·344100	.....	.....
60	22·031	233·17	41·45	191·72	0·245783	0·575542	0·253976	0·243735	0·319518	.....	.....
60	22·031	233·17	36·50	196·67	0·163855	.....	0·157711	0·249880	.....	0·268313	0·251928
58	22·031	233·17	36·05	197·12	0·161807	0·557009	0·178193	0·260120	.....	0·266265	.....
61	22·031	233·17	28·85	204·32	0·200723	0·585782	0·264217	0·328207	0·346145	.....	.....
52	25·703	241·60	43·25	198·35	0·243735	0·645181	0·301084	0·374819	0·389157	.....	.....
45	25·703	241·60	36·50	205·10	0·274458	.....	0·284699	0·368675	.....	0·387109	0·374819
45	29·375	249·05	43·25	205·80	0·251928	0·720964	0·270361	0·342048	0·378916	.....	.....
63	29·375	249·05	30·65	218·40	0·225301	0·620603	0·249780	0·327711	0·335904	.....	.....
Means	22·337	233·06	36·46	196·60	0·200382	0·581267	0·228878	0·286106	0·324070	0·307229	0·313373

TABLE No. 3.

Kind of non-conducting coating employed.	Absolute steam pressure in pounds, per square inch, within the cast iron pipe.	Fraction of a pound weight of steam of the absolute pressure in the preceding column, condensed by radiation, per hour, per sq. foot of cast iron, 0·25 inch thick, with natural surface in still air, by a difference of temperature of one degree Fahrenheit.	Fahrenheit units of heat radiated per hour in still air, from one square foot of cast iron, in its natural state, and 0·25 inch thick, for a difference of temperature of one degree Fahrenheit.
The bare or uncovered Cast Iron.....	22·031	0·00302422672	2·874757336690
The Cast Iron coated with common straw.....	22·337	0·00101234232	0·961813783953
The Cast Iron encased in pottery pipes coated with a mixture of loamy earth and chopped straw, around which, were wound wisps or tresses of common straw, there being an annular air-space between the cast iron and the pottery pipes.....	22·337	0·00116418239	1·106075136459
The Cast Iron coated with cotton waste, one inch thick.....	22·337	0·00145526806	1·382631592955
The Cast Iron coated with old felt treated with caoutchouc.....	23·867	0·00155906391	1·478214001296
The Cast Iron coated with the plastic composition or mortar of Mons. Pimont, 2·3625 inches thick, and of its natural dark-brown or mud color.....	22·031	0·00165679755	1·574911984086
The Cast Iron coated with the plastic composition or mortar of Mons. Pimont, 2·3625 inches thick, and painted white.....	23·255	0·00153873520	1·459654981866

In the condensation of steam, the heat abstracted from it is its latent heat only, the resulting water of condensation having the temperature normal to the pressure under which the condensation takes place. Now, for different pressures, the latent heat of a given weight of steam is different, becoming less and less as the pressure becomes greater and greater, but the ratio of the decrease for the latent heat is very small in proportion to the ratio of the increase of the pressure. For example: From the absolute pressure of 5 pounds per square inch to 71 pounds, the decrease in the latent heat per pound weight of steam is only 10 per centum, but if accuracy be required, it is necessary to include this difference in the calculation when the weight of steam of different pressures that will be condensed under given conditions is to be computed from the constant. The correction will be in the inverse ratio of the latent heat of steam under the absolute pressure of 22·031 pounds per square inch, to the latent heat under the pressure for which the calculation is to be made: the less the latent heat, other things equal, the more will be the weight of steam condensed. Consequently a greater weight of steam of high pressure, other things equal, will be condensed than of steam of lower pressure for a given difference of temperature between that of the steam and that of the air to which it is exposed. But although a greater *weight of steam* under these circumstances will be condensed, the *quantity of heat* lost will be only the same. In other words, the number of units of heat lost by radiation will be the same, other things equal, let the pressure of the steam or its latent heat be what it may. Hence the units of heat are not only the true measure for a particular case, but they are the universal one, being applicable to all cases, and from them the weight of steam condensable can easily be calculated for any particular pressure, the latent heat normal to that pressure being known.

An important distinction must here be drawn regarding the economic loss of heat due to the condensation of steam by external radiation, as to whether that condensation takes place in the boiler and steam-jacket of a steam-engine, or in the steam-pipe and steam-cylinder. In the first case, the loss is simply of the latent heat of the steam; but in the second case, it is of the total heat of the steam above zero Fahrenheit less the Fahrenheit temperature of the feed-water. For example: In an ordinary condensing steam-engine the temperature of the feed-water is say 100 degrees Fahrenheit, and

the pressure of the steam in the boiler is say 60 pounds per square inch absolute. The total heat of this steam above the zero of Fahrenheit is 1203 units, leaving the quantity of heat imparted to it by the fuel 1103 units, the whole of which is lost when the condensation takes place in the steam-pipe and steam-cylinder; because the resulting water of condensation is not returned to the boiler with the temperature normal to the pressure under which it was condensed. But when the condensation takes place in the boiler and steam-jacket, only the latent heat, amounting in the example to 908 units, is lost, because the resulting water of condensation is returned to the boiler with the temperature normal to the pressure under which it was condensed. In the example, therefore, the economic loss of heat by the condensation due to external radiation, is $\left(\frac{1203}{908}\right) = 32\frac{1}{2}$ per centum greater when that condensation takes place in the steam-pipe and steam-cylinder than when it takes place in the boiler and steam-jacket. It is thus apparent that even as regards the loss of heat by external radiation, a material gain can be realized by the use of a steam-jacket; and also that when a steam-jacket is used, the steam-pipe should discharge into it and not directly into the cylinder, which latter should draw its steam from the jacket. By such an arrangement nearly one-third of the fuel required to supply the loss of heat by the external radiations from the steam-pipe and from the unjacketed steam-cylinder, can be saved, even after allowing for the greater external surface of the steam-jacket than of the cylinder it protects. Of course, the narrower the annular space separating the two, the greater will be the benefit of the jacketing; which thus extends, not only to the cylinder, but to the steam-pipe when the latter discharges into the jacket. I am not aware that these facts have ever before been pointed out.

Returning now to an examination of the experimental results, we find that of the different non-conducting substances tried, the most efficient was common straw (1st Group, Table No. 2), and its application reduced the loss of heat by radiation from the bare steam-pipes 66·54 per centum.

The next most efficient non-conductor was the pottery-pipes coated with a mixture of loamy earth and chopped straw, around which were wound wisps or tresses of common straw, there being an annular air space between the steam-pipe and the pottery-pipe (3d Group, Table

No. 2). The application of this system reduced the loss of heat by radiation from the bare steam-pipes 61·52 per centum.

The third place in non-conducting efficiency was held by cotton waste, that is broken cops as they come from the machines for weaving cotton cloth (4th Group, Table No. 2). Its application in one inch thickness reduced the loss of heat by radiation from the bare steam-pipes 51·21 per centum.

The fourth place in non-conducting efficiency was held by the old felt which had been treated with caoutchouc and used on printing machines (2d Group *bis*, Table No. 2). Its application in unknown thickness reduced the loss of heat by radiation from the bare steam-pipes 48·58 per centum. The experiments with this substance being but two in number and its thickness unknown, but little use can be made of its constant with confidence.

Last in non-conducting efficiency was the plastic composition of Mons. Pimont, consisting essentially of clay mixed with cows' hair and perhaps other substances, and kneaded with water (5th group, Table No. 2). Its application in 2·3625 inches thickness reduced the loss of heat by radiation from the bare steam-pipes 45·22 per centum, the composition being of its natural dark brown or mud color.

Three experiments (5th group, *bis*, Table No. 2) were made with this composition painted white, with a view to ascertain whether its heat radiating quality was affected by color. The experiments were too few to establish the fact with certainty, but taking them as they stand, they show a reduction of 7·32 per centum in the heat lost by radiation from the same substance in its natural dark brown or mud color.

The preceding Table No. 3 shows the quantity of heat radiated per hour in still air from one square foot of 0·25 inch thick cast iron steam-pipe surface in its natural state, for a difference of temperature on the two sides of one degree Fahrenheit, when bare and when coated with the non-conducting substances hereinbefore described. The quantity of heat is expressed both in fractions of a pound weight of steam condensed, and in Fahrenheit units.

The following example illustrates the practical use of the constants in Table No. 3. Suppose an area of 100 square feet of bare cast iron 0·25 inch thick, to have upon one side an absolute steam pressure of 55 pounds per square inch, and upon the other side still air of

60 degrees Fahrenheit temperature, what weight of steam would be condensed per hour by the heat radiation from the 100 square feet of surface under the supposed conditions?

The temperature of steam of 55 pounds absolute pressure per square inch is 287 degrees Fahrenheit, and the latent heat is 912 Fahrenheit units. The difference between the temperatures of the steam and of the air is 227 degrees Fahrenheit. Then, as the constant for the bare cast iron is 2·874757336690, the weight of steam that would be condensed per hour by the surface is $\left(\frac{2\cdot874757336690\times227\times100}{912}\right)=71\cdot55392$ pounds. And the Fahrenheit units of heat that would be radiated per hour from this surface would be $(2\cdot874757336690\times227\times100)=65256\cdot99154$.

REPORT OF THE TRIALS OF THE STEAM-MACHINERY OF THE U. S. REVENUE STEAMERS "RUSH," "DEXTER," AND "DALLAS,"*

AT THE U. S. NAVY YARD, BOSTON, MASS., IN THE MONTH OF AUGUST, 1874, BY A JOINT BOARD OF U. S. NAVAL AND U. S. REVENUE-MARINE ENGINEERS.*

In the early part of the present season there were completed for the U. S. Revenue Marine, three new revenue steamers, named, respectively, in honor of ex-Secretaries of the Treasury, the "Rush," the "Dexter," and the "Dallas." The three vessels are similar as respects the hulls, the screws, and the boilers, but the engines are different each from the other—that of the "Rush" being a compound engine; that of the "Dexter" a high-pressure condensing engine; and that of the "Dallas," a low-pressure condensing engine.

The vessels are each 140 feet long over all, 129½ feet between perpendiculars at water line, 23 feet extreme breadth of beam, and 10 feet depth of hold. The draught of water aft is about 8 feet 10 inches. The hulls are of wood. The vessels represent the smallest type of full-powered screw revenue cutters adapted for cruising pur-

*[Communicated to this JOURNAL by Chas. E. Emery, C. E.—Ed.]

poses. They were all intended to be rigged as schooners, but it having been decided to send the "Rush" to the Pacific Coast, she was rigged as a top-sail schooner. One of the vessels averaged upward of eleven nautical miles per hour for six consecutive hours on her trial trip, and neither of them averaged less than ten knots, the machinery being entirely new in each case.

Each vessel has one boiler, 11 feet wide on base and 9 feet high, with a double segmental shell, each portion being 6 feet 2 inches in diameter. There are three furnaces in each boiler, located between water legs attached to the bottom of the shell. The products of combustion return through tubes within the shell. The boiler of the "Dallas," designed for low-pressure steam, is 13 feet 9 inches long, the front connection being built in and the steam chimney attached to the boiler. The boilers of the two other vessels were designed for high-pressure steam, and are each 12 feet long, independent of front connection, which is a separate structure, bolted on. The steam chimney is also a separate structure, connected to boiler by a large tube. The boiler of the "Dallas" has 160 tubes 3¼ inches in diameter and 9 feet 3 inches long. The boilers of the two other vessels have each 158 tubes 3¼ inches in diameter and 9 feet 8 inches long.

The "Rush" is propelled by a compound engine, with vertical cylinders and intermediate receiver, arranged fore and aft at the same level, the pistons being separately connected to cranks at right angles. The cylinders are thoroughly steam-jacketed, felted, and lagged, and are, respectively, 24 and 38 inches in diameter, with 27 inches stroke of piston. The steam is distributed to the high-pressure cylinder by a short slide-valve with adjustable cut-off plates sliding on back of same. The distribution of steam to the low-pressure cylinder is effected by means of a double-ported slide-valve with lap proportioned to cut off the steam at about half-stroke. The surface condenser is arranged on the starboard side. It supports two main columns from the cylinders, and contains 900 square feet of condensing surface. The air-pump is operated from the cross-head of the low-pressure engine. The circulating pump is of the centrifugal type operated by a small engine, directly connected. The screw is 8 feet 9 inches in diameter with mean pitch of 14½ feet. The engine was intended to be operated regularly with a steam pressure of 80 pounds, but during the trials, hereafter referred to, it was reduced to corres-

pond to the pressure carried on the trial of the "Dexter." The machinery was designed by Charles E. Emery, consulting engineer, and built by the Atlantic Works, East Boston, Massachusetts, the contractors for the vessel complete.

The "Dexter" was also built under contract with the Atlantic Works of East Boston, Massachusetts. The engine of this vessel was built from designs of that establishment, and is of the inverted type, with a single cylinder 26 inches in diameter and 36 inches stroke of piston. The cylinder is not jacketed, but is carefully felted and lagged. Steam is distributed by a short slide-valve, with adjustable cut-off plates sliding on back of same. The condenser is located outside the frame, but it and the air and circulating pumps are exact duplicates of those in the "Rush." The engine and boiler are designed to be operated with a maximum steam pressure of 70 pounds.

The "Dallas" was built under contract with the Portland Machine Works, of Portland, Maine. The engine was designed in that establishment, and is of the inverted type, with a single cylinder 36 inches in diameter, with 30 inches stroke of piston. The cylinder is not steam-jacketed, but is carefully covered with non-conducting composition and lagged. Steam is distributed by a short slide valve, with adjustable cut-off plates sliding on back of same. The surface condenser is located under starboard frames and has the same condensing surface as those in the other vessels. The air and circulating pumps are also substantially the same. The engine and boiler are designed to be operated with a maximum steam pressure of 40 pounds.

The opportunity presented of testing, in these vessels, the relative merits of the three kinds of engines attracted considerable attention. Several manufacturers and engineers expressed a desire that competitive trials be made. A correspondence on the subject was opened between the Navy and Treasury Departments, which resulted in an agreement for a trial under the direction of persons representing both services, and the undersigned, Chief Engineer Chas. H. Loring, U. S. N., and Chas. E. Emery, consulting engineer, were selected in behalf of the Navy and Treasury Departments, respectively, to make preparations for and take general charge of the trials.

When the preparations were complete, the following officers were detailed to conduct the experiments, viz.: Chief Engineer Edward Farmer, U. S. N.; Chief Engineer Geo. D. Emmons, U. S. N.; Chief

Engineer F. H. Pulsifer, U. S. R. M.; and Chief Engineer F. A. D. Bremon, U. S. R. M. As assistants to these gentlemen there were detailed Past Assistant Engineers Harvey and Cook, U. S. N.; Assistant Engineer Tobin, U. S. N., and Mr. E. Hugentobler. The care of the machinery was entrusted to the engineers of the respective vessels. The chief engineers detailed for the experiments stood regular watches with an assistant while the experiments were in progress, and at the close certified duplicate copies of the logs, which are deposited in the Navy and Treasury Departments, respectively. They also computed the principal results for their own satisfaction, and returned to their regular duties, but two of the assistants were retained to assist the undersigned in making out a statement in detail, which is presented in the annexed table.

MANNER OF MAKING THE EXPERIMENTS.

The experiments were made with the vessel secured to the wharf.

The coal, which was anthracite of fair quality, was broken on the wharf to proper size (the vessel's bunkers having been closed and sealed) and filled into bags to a certain weight.

The bags were sent on board when ordered by the senior engineer on watch, he making record on the log of the number of bags and the time of receipt; a similar record being made by one of the men on the wharf. At the end of the hour the number of bags of coal actually put on the fire was reported from the fire-room and entered in the appropriate column. The several records agreed with each other, and the total amount expended corresponded with the total number of bags filled on the wharf. The ashes were measured into buckets of which the mean weight was ascertained and tallied as they were hoisted out. They were afterwards weighed in gross on the wharf, and the two accounts found to agree substantially.

The feed-water was measured, after its delivery from the surface-condenser and before its return to the boiler, for which purpose a tank of boiler-plate was especially constructed, having a plate dividing it vertically into two equal parts.* In the upper edge of the plate was cut a rectangular notch eight inches long, by which the height to which each half of the tank could be filled was determined. The mean of the weight of water which the half tanks contained was 1129½

* [A description of this tank appears among the Editorial Items.—Ed.]

TABLE (No. 2.) SHOWING THE RESULTS OF EXPERIMENTS WITH THE STEAM MACHINERY OF THE U. S. REVENUE STEAMERS "RUSH," "DEXTER,"

JOINT BOARD OF U. S. NAVAL AND U. S. REVENUE MARINE ENGINEERS. (TO ACCOMPANY REPORT OF CHIEF ENGINEER CHARLES H. LO

E. EMERY, CONSULTING ENGINEER, SENIOR MEMBER REPRESENTING U. S. TREASURY DEPARTMENT.)

	NAME OF STEAMER		"RUSH."				"DEXT			
	STYLE OF ENGINE		COMPOUND.				HIGH PRESSURE			
1	Dimensions of Engines	Diameter of cylinders, inches	Small. 24		Large. 38					26
2		Stroke of pistons, "	27		27					36
3		Size of cylinder ports, "	18 by 1¾		2 of 27 by 1 3-16					16 b
4		Ratio of displacement to clearance and passages	.07887		.05849					.0
5	Governing dimensions of Boilers (horizontal tubular type	Grate surface, square feet	57.							57
6		Heating surface, " "	1572.85							1572.8
7		Cross area tubes for draft, " "	7.74							7.7
8		Ratio grate to heating surface	27.58							27.5
9		Ratio cross area tubes to grate surface	7.37							7.3
10	Designation of Experiments	NUMBER FOR REFERENCE	1		2		3	4	5	6
11		DESIGNATION IN LOG	Long run, Rush.		A.		B.	C.	Long run, Dexter.	D.
12	Time	DATE OF EXPERIMENT, 1874	H. P. Eng. | L. P. Eng. Aug. 3 to 6.		H. P. Eng. | L. P. Eng. Aug. 6.		Aug. 17	Aug. 17.	Aug. 14-16.	Aug.
13		DURATION OF EXPERIMENT, hours	55		6		2.9166	1.4166	34.5	0.6
14	Steam Cut-off and Expansion	Average steam pressure in boiler, lbs.	69.06		36.781		68.70	69.286	67.12	66.4
15		" " " " intermediate chamber, "		5.531		4.34				
16		" cut-off in fractions of stroke	.35095	.4652 Both.	.5976	.5292 Both.	.1827	.2335	.2483	.3
17		Ratio of expansion	2.4586	6.2157	1.5948	4.0301	4.4573	3.6688	3.489	2.7
18	Vacuum and Barometer	Average vacuum in condenser, inches	26.495		26.21		25.862	25.187	25.45	25.3
19		" barometer, "	30.1757		30.147		30.195	30.195	30.143	30.1
20		" " " lbs.	14.8122		14.798		14.821	14.821	14.796	14.8
21	Temperatures (Fahrenheit Scale)	Air. Average temperature external air, degrees	66.23		66.00		67.66	64.2	63.37	66.2
22		" " " engine room, "	87.86		84.23		78.428	79.6	82.27	85.4
23		Water. " " " sea water, "	59.96		59.615		66.00	65.00	63.66	65.8
24		" " " discharge water, "	90.56		93.77		99.857	104.8	102.45	100.1
25		" " " hot well, "	110.306		108.77		115.74	121.	113.60	119.2
26		" temp. feed water from tanks, "	114.04		114.42				113.65	
27	Revolutions	Total revolutions	233773.		19971.		9887.	5466.	126403.	2840.
28		Average " per hour	4250.42		3328.5		3289.83	3858.35	3063.85	4969.23
29		" " per minute	70.8403		55.475		56.497	64.3059	61.0642	72.82
30	Indicator Diagrams	Average initial pressure in cyl. above atmosphere, lbs.	67.467	8.65	35.4473	7.1842	65.613	64.500	64.4095	62.15
31		" total initial pressure in cylinder, "	82.2772	23.4622	50.2453	21.9822	80.434	79.321	79.2055	76.97
32		" " terminal " " "	29.4412	9.222	27.8506	9.1664	15.344	17.642	16.8746	21.63
33		" " cushion " " "	31.7392	11.1062	29.0618	8.048	7.503	8.536	8.267	10.32
34		Portion stroke where cushion press. were measured	.8888 Maximum.	Full.	.9005 Maximum.	Full.	Full.	Full.	Full.	Full.
35		Average back pressure in cylinder, lbs.	9.50	3.4611	8.2305	3.415	3.4487	3.7317	3.6550	5.27
36		" mean effective pressure in cylinder, "	29.6848	12.7246	18.8818	12.2997	34.439	37.1274	37.5376	42.02
37		" " total pressure in cylinder, "	39.1848	16.1857	27.1123	15.7147	37.8877	40.8591	41.1926	47.29
38		Estimated friction pressure, "	2.5	1.5	2.5	1.5	3.00	3.00	3.00	3.00
39	Power	Indicated horse-power (effective)	127.918	Both. 266.547	63.717	Both. 168.652	185.872	228.077	218.972	292.37
40		Net horse-power	117.145	Both. 239.432	53.0367	Both. 145.1745	169.680	205.348	201.472	271.50
41		Total horse-power	127.918	Both. 304.254	63.717	Both. 197.787	204.485	251.001	240.293	329.03

[CONCLUDED ON NEXT PAGE.]

MACHINERY OF THE U. S. REVENUE STEAMERS "RUSH," "DEXTER," AND "DALLAS," MADE AT THE U. S. N
S. (TO ACCOMPANY REPORT OF CHIEF ENGINEER CHARLES H. LORING, U. S. N., SENIOR MEMBER REPRES
TREASURY DEPARTMENT.)

"RUSH."			"DEXTER."							
COMPOUND.			HIGH PRESSURE, CONDENSING.							
ll.	Large.									
	38					26				
	27					36				
1¼	2 of 27 by 1 3-16					16 by 2				
7887	.05849					.0537				
	57.					57				
	1572.85					1572.85				
	7.74					7.74				
	27.58					27.58				
	7.37					7.37				
, Rush.	2 A.		3 B.	4 C.	5 Long run, Dexter.	6 D.	7 G.	8 F.	9 E.	
L. P. Eng. to 6.	H. P. Eng. Aug. 6.	L. P. Eng.	Aug. 17	Aug. 17.	Aug. 14-16.	Aug. 17.	Aug. 17.	Aug. 17.	Aug. 17,	A
	6		2.9166	1.4166	34.5	0.630	1.3166	1.200	0.9166	
	36.731		68.70	69.286	67.12	66.42	40.625	39.9	41.875	
5.531		4.34								
.4652	.5976	.5292	.1827	.2335	.2483	.3331	.262	.38114	.4518	
Both.		Both.								
6.2157	1.5948	4.0301	4.4573	3.6088	3.480	2.7339	3.3377	2.4932	2.0645	
495	26.21		25.862	25.187	25.45	25.310	26.10	26.00	25.541	
1757	30.147		30.195	30.195	30.143	30.195	30.195	30.195	30.195	
8122	14.798		14.821	14.821	14.796	14.821	14.821	14.821	14.821	
23	66.00		67.66	64.2	63.37	66.285	66.33	67.00	67.00	
86	84.23		78.428	79.6	82.27	85.428	86.00	86.00	85.66	
96	59.615		66.00	65.00	63.66	65.859	67.66	66.66	67.00	
56	93.77		99.857	104.8	102.45	100.14	99.66	95.66	99.00	1
306	108.77		115.74	121.	113.60	119.28	107.33	108.66	117.33	1
04	114.42				113.65					
42	19071.		9887.	5466.	126403.	2840.	4017.00	3978.	3338.	44
8403	3328.5		3389.83	3858.35	3663.85	4369.23	3050.88	3315.00	3641.45	29
	55.475		56.497	64.3059	61.0642	72.8205	50.8481	55.25	60.6909	
8.65	35.4473	7.1842	65.613	64.500	64.4095	62.155	37.50	36.55	38.812	
23.4622	50.2453	21.9822	80.434	79.321	79.2055	76.976	52.321	51.371	53.633	
9.222	27.8506	9.1664	15.344	17.642	16.8746	21.633	13.134	15.771	19.008	
11.1062	29.0618	8.048	7.503	8.536	8.267	10.321	6.258	8.771	9.196	
Full.....	.9005	Full.....	Full.....	Full.....	Full.....	Full.....	Full.....	Full.....	Full.....	Fu
	Maximum.									
3.4611	8.2305	3.415	3.4487	3.7317	3.6350	5.2710	3.1570	3.6347	4.3137	
12.7246	18.8818	12.2997	34.439	37.1274	37.5376	42.0285	25.5826	30.6649	33.8385	
16.1857	27.1123	15.7147	37.8877	40.8591	41.1926	47.2995	28.7396	34.2996	38.1522	
1.5	2.5	1.5	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
Both.		Both.								
266.547	63.717	168.632	185.872	228.077	218.972	292.370	124.267	161.848	196.187	1
Both.		Both.								
239.432	53.0067	145.1745	169.680	205.348	201.472	271.501	109.694	146.015	178.794	1
Both.		Both.								
304.254	63.717	197.787	204.485	251.001	240.293	329.036	139.602	181.032	221.197	1

THE U. S. NAVY YARD, BOSTON, MASS., AUGUST 1874, BY A
MBER REPRESENTING U. S. NAVY DEPARTMENT, AND CHARLES

	"DALLAS."				
	LOW PRESSURE, CONDENSING.				
			86		
			30		
			33 by 2¼		
			.0802		
			57		
			1689.24		
			7.84		
			49.63		
			7.27		
9	10	11	12	13	14
E.	L.	K.	Long run Dallas.	J.	H.
Aug. 17,	Aug. 23.	Aug. 23	Aug. 20-21.	Aug. 22.	Aug. 23.
0.9166	1.5166	1.550	31.	1.60	1.5333
41.875	35.40	35.286	31.96	33.7	27.40
.4518	.13296	.19723	.26445	.28774	.38585
2.0645	5.0674	3.8036	3.1341	2.9358	2.3176
25.541	26.08	26.00	25.30	29.063	24.790
30.195	30.080	30.080	29.907	30.080	30.080
14.821	14.765	14.765	14.7345	14.765	14.765
67.00	69.75	72.00	74.35	72.66	69.833
85.66	75.25	76.80	88.20	76.83	73.166
67.00	67.75	68.00	68.75	66.00	67.666
99.00	103.50	100.00	98.93	103.50	108.66
117.33	122.00	122.00	128.41	128.66	134.00
			122.76		
3398.	4480.	5294.	114426.	6190,	5839.
3641.45	2920.88	3415.48	3691.16	3868.75	3808.04
60.6909	48.6813	56.9248	61.5193	64.4791	63.4674
38.812	32.14	32.275	31.8367	31.065	24.666
53.635	46.905	47.040	46.5832	45.860	39.431
19.008	9.475	11.860	12.6810	14.008	14.7783
9.196	5.065	5.194	6.1595	5.875	6.182
Full.....	Full.....	Full.....	Full.....	Full.....	Full.....
4.3137	2.9730	3.3678	3.9073	4.1101	4.0911
33.8385	18.5215	21.4471	23.5255	24.6107	24.1264
38.1522	21.4945	24.8149	27.4328	28.7208	28.2175
3.00	2.5	2.5	2.5	2.5	2.5
196.187	137.962	186.805	221.447	242.807	234.295
178.794	119.340	165.030	197.915	218.137	210.017
221.197	160.107	216.139	258.228	283.357	274.024

pounds, at a temperature of 72 degrees Fahrenheit. In the computations for each experiment, the weight of water is reduced to correspond with mean temperature.

One of the feed-pumps was disconnected from the check-feed valve, and its discharge pipe led to a small receiving tank placed over the two halves of the measuring tank, into which this pump forced the condensed water from the hot well. The receiving tank had on its bottom two cocks, one over each half-tank, so that either could be filled from it at will.

The other feed pump had its suction pipe detached from the hot well and connected with the bottoms of the two half-tanks, through a cock on each, so that the contents of either could be drawn out and discharged with the boiler.

The method of measuring the water and recording it was as follows: One side having been filled, the cock over it on the receiving tank was closed and the other over the empty half opened. When the water in the full one had settled to the height of the edge of the notch, its cock in the feed-pipe was opened and the contents pumped into the boiler (care being taken to empty one in less time than it required to fill the other); when empty, its feed-cock was closed. When the water in the tank, being filled, reached within a few inches of the notch, a gong in the engine-room was sounded to call attention, and when it reached the notch the gong was struck twice; at this instant the assistant engineer in the engine-room noted the reading of the counter, and an attendant in the fire-room noted and reported the height of water in the glass gauge on the boiler, as shown by a scale of inches secured to it. The attendant at the tank also noted the time of filling, and the temperature when the tank was half emptied. After entering the number of the counter in the log, the assistant engineer ascertained the numerical difference between that and the preceding entry, and if it was far from the average its cause was sought for.

By this system of checks all errors of record could be detected, and it was possible to preserve and utilize any continuous run which came to an end through derangement of the engine. All parts of the tanks, pipes and cocks were plainly visible to the eye, and had any leaks occurred therein they must have been detected. That the condensers were tight was evident from the fact that the water remained quite fresh in the boilers.

The water lost from ordinary causes in the circulation to and from the engine and boiler was replaced by running hydrant water into the tank that was being filled. The additional water was therefore measured and charged in the cost.

The loss of water was not sufficient to affect the result materially in either case. It was greatest in the "Dexter," which had been on service. The safety-valve of this vessel leaked slightly, and there was probably some other trifling leak that could not be detected. The number of inches that the water fell in the boiler between the periods of supply being shown in the logs, were added together, and from the same and known dimensions of boiler the volume and weight lost were ascertained quite accurately. The reduction in the number of revolutions per tank, when the water was being received from the hydrant, furnished another and perhaps still more accurate means of ascertaining the proportionate amount lost and returned. The two methods closely agreed in fixing the loss in the case of the "Dexter" at 4·96 per cent. of the total amount of water used.

A number of indicators were tested with steam before the trials, and a pair selected for use which proved correct by a standard gauge at varying pressures. Indicator diagrams were taken every twenty minutes throughout the trials, and the data for the usual columns of the log, except the coal and ashes, every half hour.

It was ascertained that the pistons of the "Dexter" and "Dallas" were tight by removing the cylinder covers and letting on full steam pressure.

During the first and principal experiments with each vessel the boilers were worked at their maximum power with natural draft at the dock, the fires being cleaned regularly as at sea, and the cut-offs being adjusted to carry a steam pressure of about 70 pounds during trial of the "Rush" and "Dexter," and about 35 pounds during that of the "Dallas."

At the conclusion of the principal experiments on each vessel, shorter experiments, designated in the table by letters, were made to determine the effect of varying the degree of expansion at the approximate steam pressures of 70 and 40 pounds. In the case of the "Dexter" the cut-off was shortened for one experiment as much as the gear provided would permit, and for this vessel, as well as for the "Dallas," the cut-off was gradually lengthened, during other experiments, as far as the boiler would supply steam at the pressure desired.

TABLE (No. 2.) SHOWING THE RESULTS OF EXPERIMENTS WITH THE STEAM MACHINERY OF U.

	NAME OF STEAMER			"RUSH."		"DEXTER				
	STYLE OF ENGINE			COMPOUND.		HIGH PRESSURE, CO				
10	Designation of Experiments		NUMBER FOR REFERENCE	1	2	3	4	5	6	
11			DESIGNATION IN LOG	Long run, Rush.	A.	B.	C.	Long run, Dexter.	D.	
42	Water	Actual.	Total weight feed water measured, lbs.	266967.	21305.35	12944.05	7831.95	178867.	4477.31	
43			Revolutions using same	231571.	18942.	9895.00	5493.00	125197.	2752.00	
44			Time using same, hours	54.482	5.69085	2.919	1.4236	34.1708	0.6298	
45			Water per hour per tank measurement, lbs.	4900.103	3726.24	4434.373	5501.36	5234.505	7108.44	
46		Indicated.	" " " " indicator diagrams, "	4568.231 | 3604.00	3328.51 | 2857.56	3018.794	3932.24	3576.088	5420.34	
47			Proportion of water actually used accounted for by indicator	.9333 | .7355	.8933 | .7669	.6808	.7148	.6832	.7625	
48	Coal and Refuse		Total coal consumed, lbs.	35700.				23655.5		
49			Average coal consumed per hour "	649.091				685.667		
50			Coal consumed per square foot of grate per hour "	11.388				12.029		
51			Percentage refuse from coal	20.978				20.291		
52			Combustible per hour, lbs.	512.925				546.588		
53	Performance of Engine	Water.	Water per indicated h. p. per hour by tanks, lbs.	18.3836	22.0943	23.8572	24.1202	23.905	24.3131	
54			" " " " " " by indicator "	17.138 | 13.521	19.736 | 16.9435	16.2278	17.2408	16.3303	18.5390	
55			" " net " " " "	20.4626	25.6073	26.1357	26.2405	25.9813	26.1820	
56			" " total " " " "	16.1032	18.8397	21.6856	21.9178	21.784	21.6037	
57	Performance of Engine and Boiler	Coal.	Coal per indicated horse-power per hour, lbs.	2.4352				3.1313		
58			" " net " " " "	2.7110				3.4033		
59			" " total " " " "	2.1334				2.8534		
60		Combustible.	Combustible per indicated horse-pow'r per hour "	1.9243				2.4959		
61			" " net " " " "	2.1423				2.7127		
62			" " total " " " "	1.6858				2.2744		
63	Performance of Boiler	Coal.	Water evaporated per lb. coal at observed pressure and temperature, lbs.	7.5492				7.6342		
64			Equivalent evaporation from atmospheric pressure and temperature, 100°, "	7.6712				7.7789		
65			Equivalent evaporation from atmospheric pressure and temperature, 212°, "	8.5675				8.6878		
66		Combustible.	Water evaporated per lb. combustible at observed pressure and temperature, "	9.5533				9.5776		
67			Equivalent evaporation from atmospheric pressure and temperature, 100°, "	9.7076				9.7591		
68			Equivalent evaporation from atmospheric pressure and temperature, 212°, "	10.8420				10.8994		
69	Calculated maximum performances based on water actually used in the different engines, but calculated for boilers of different proportions using different kinds of fuel		Coal per indicated horse-power per hour, with boilers proportioned to evaporate 9 lbs. water per lb. of coal, at pressure and temperature actually used (probably the maximum which can be obtained at sea, burning anthracite coal),	2.0426				2.656		
70			Coal per indicated horse-power per hour, using slow combustion in best land boilers, or best Welch coal in marine boilers, so proportioned that there will be evaporated 10 lbs. of water per lb. of coal at pressure and temperature actually employed	1.8384				2.3905		
71	14 Steam and expansion (repeated).		Average steam pressure in boiler	69.06	36.731	68.70	69.286	67.12	66.42	
72	17		Ratio of expansion	6.2157	4.0901	4.4578	3.6088	3.489	2.7239	
73	Relative performances		By comparison of combustible consumed	1.				1.2970		
74			By Comparison of water used per tank measurement	1.	1.2018	1.2977	1.3130	1.3003	1.3225	
75				.7690	.9243	.9980	1.0090	1.	1.0171	
76				.7700	.9201	1.	1.0110	1.0000	1.0191	
77				.6823	.8300	.8855	.8952	.8872	.9023	
78				.8320	1.	1.0798	1.0917	1.0819	1.1004	
79				.6889	.8279	.8940	.9068	.8958	.9110	
80				.6363	.7671	.8288	.8374	.8300	.8441	

USH."		"DEXTER."							
MPOUND.		HIGH PRESSURE, CONDENSING.							LO
	2 A.	3 B.	4 C.	5 Long run, Dexter.	6 D.	7 G.	8 F.	9 E.	10 L.
	21205.35 18042. 5.69085 3796.24	12944.05 9895.00 2.919 4434.373	7831.95 5493.00 1.4236 5501.26	178897. 125197. 34.1708 5234.505	4477.31 2752.00 0.6298 7108.44	4660.93 2973.00 1.3022 3579.15	5605.7 3968.00 1.1969 4693.19	5745.52 3455.00 .9213 6235.96	5592.79 4437. 1.5191 3681.74
	3328.51 | 2857.56	3018.794	3982.94	3576.088	5490.94	2541.96	5019.52	3988.28	2648.88
55	.8933 | .7669	.6808	.7148	.6832	.7625	.6543	.6448	.6396	.7195
				23655.5 685.607 12.029 20.291 546.538					
1	22.0943 19.736 | 16.9435 25.6673 18.8397	23.8572 16.2278 26.1337 21.6856	24.1202 17.2408 26.2405 21.9178	23.905 16.3303 25.9813 21.784	24.3131 18.5390 26.1820 21.6087	28.802 18.8462 32.6284 25.6383	28.9356 18.6564 32.0734 25.8694	31.7864 20.3290 34.8786 28.1924	26.6866 19.2000 30.8508 22.9055
				3.1313 3.4033 2.8584					
				2.4939 2.7127 2.2744					
				7.6342					
				7.7789					
				8.0878					
				9.5776					
				9.7591					
				10.8994					
				2.656					
				2.3905					
	36.731 4.0301	68.70 4.4573	69.286 3.6688	67.12 3.489	66.42 2.7239	40.625 3.3377	39.9 2.4232	41.875 2.0845	35.40 5.0674
				1.2970					
	1.2018 .9243 .9261 .8300 1. .8279 .7671	1.2977 .9980 1. .8855 1.0798 .8940 .8283	1.3120 1.0090 1.0110 .8952 1.0917 .9038 .8374	1.3008 1. 1.0020 .8872 1.0819 .8958 .8300	1.3225 1.0171 1.0191 .9023 1.1004 .9110 .8441	1.5667 1.2048 1.2073 1.0689 1.3036 1.0793 1.	1.5789 1.2104 1.2129 1.0739 1.3096 1.0843 1.0046	1.7291 1.3297 1.3324 1.1797 1.4387 1.1911 1.1037	1.4516 1.1164 1.1186 .9904 1.2078 1. .9265

CHARLES H. LORING, CHIEF EN
CHARLES E. EMERY, CONSULTING

"DALLAS."

LOW PRESSURE, CONDENSING.

10 L.	11 K.	12 Long run Dallas.	13 J.	14 H.
5592.79	7829.9	183893.	11166.02	11149.61
4437.	5310.	113759.	6156.	5847.
1.5191	1.5547	30.8192	1.59121	1.5354
3681.74	5086.83	5066.83	7017.30	7261.54
2648.88	3871.18	4442.12	5148.68	5336.16
.7195	.7687	.7445	.7337	.7348
.....	.....	23533.75	.....	.....
.....	.....	758.831	.....	.....
.....	.....	13.313	.....	.....
.....	.....	20.508	.....	.....
.....	.....	603.247	.....	.....
26.6866	26.9608	26.9447	28.9007	30.9933
19.2000	20.7230	20.0595	21.2048	22.7758
30.8508	30.5176	30.1484	32.1693	34.576
22.9955	23.3014	23.1069	24.7649	26.4996
.....	.....	3.4267	.....	.....
.....	.....	3.8341	.....	.....
.....	.....	2.9386	.....	.....
.....	.....	2.7241	.....	.....
.....	.....	3.0480	.....	.....
.....	.....	2.3361	.....	.....
.....	.....	7.8632	.....	.....
.....	.....	7.8458	.....	.....
.....	.....	8.7025	.....	.....
.....	.....	9.8912	.....	.....
.....	.....	9.8693	.....	.....
.....	.....	11.0225	.....	.....
.....	.....	2.994	.....	.....
.....	.....	2.694	.....	.....
35.40	35.286	31.96	33.7	27.40
5.0674	3.8936	3.1341	2.9358	2.3176
.....	.....	1.4156	.....	.....
1.4516	1.4665	1.4657	1.5721	1.6860
1.1164	1.1278	1.1272	1.2060	1.2965
1.1186	1.1301	1.1294	1.2114	1.2991
.9904	1.0006	1.	1.0726	1.1503
1.9078	1.2302	1.2196	1.3081	1.4038
1.	1.0102	1.0097	1.0805	1.1614
.9265	.9360	.9355	1.0084	1.0761

The long runs having demonstrated the evaporative qualities of the boilers, record was made during the short runs of the amount of water used only; from this quantity of coal necessary to evaporate it can easily be obtained. It would have been impossible to distribute properly the coal consumed during the short runs which followed each other immediately. While these runs were in progress an officer was stationed at the tanks and one in the fire-room, in addition to the usual number on watch, to avoid the possibility of error.

In the annexed table we have endeavored to show accurately, in condensed form, the results of the trials of the particular machinery described under the particular conditions named.

The actual performances will be found in lines 53 to 68, inclusive, of the table, the previous lines showing the several observed and computed quantities from which the performances were calculated.

As previously stated the boiler during the principal experiments on each vessel was operated at maximum power, and the results show that the evaporation was fully equal to that obtained in ordinary practice, but inasmuch as on land, and occasionally in steamers where space will permit, it is the practice to use a slower rate of combustion in comparatively larger boilers, thereby increasing the evaporative effect, there has been added to the table, for comparison under such circumstances, lines 69 and 70, showing the performances compared on the basis of the water actually used, but with boilers of such proportions or using such variety of coal that the evaporation will equal nine and ten pounds, respectively, per pound of coal.

The relative performances shown decimally in lines 73 to 80, inclusive, with different experiments as unity, will be found convenient for comparison.

It is believed that the other portions of the table will be fully understood without discussion or further explanation on our part.

Annexed will be found specimens of the Indicator Diagrams taken during the principal runs.

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Chief Engineer, U. S. N.

CHAS. E. EMERY,
Consulting Engineer, U. S. R. M.

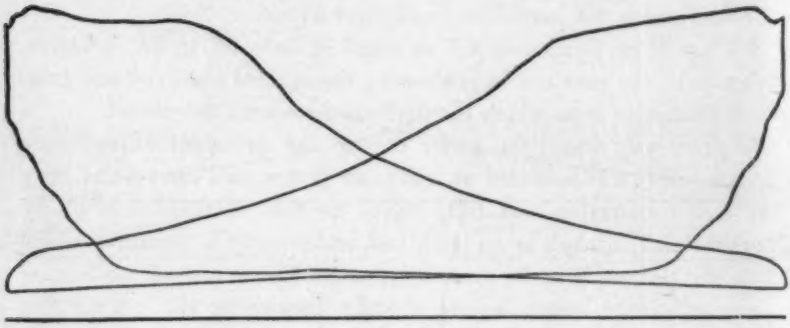
October 10, 1874.

INDICATOR DIAGRAMS.

U. S. REVENUE-STEAMER, "RUSH."

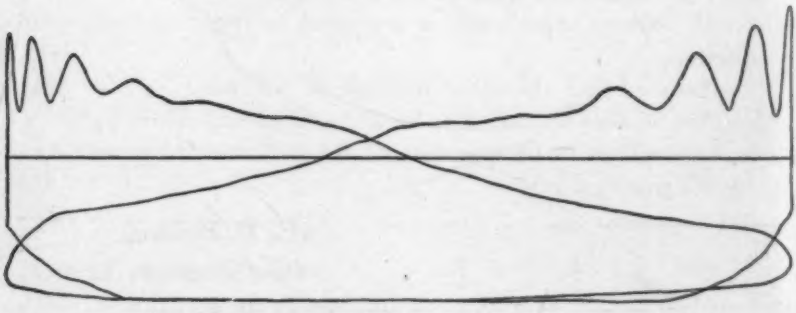
High-Pressure Cylinder.

Scale of indicator, 40 pounds per inch.



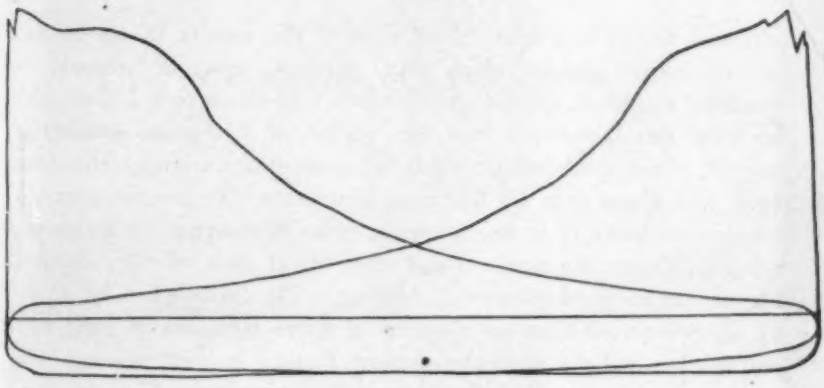
Low-Pressure Cylinder.

Scale of indicator, 13 pounds per inch.



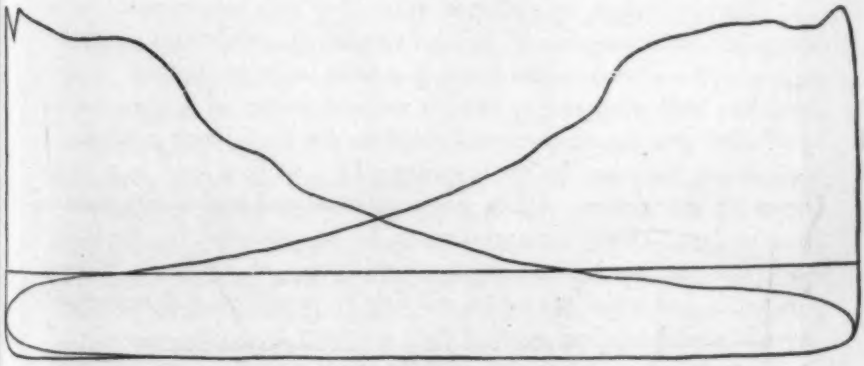
U. S. REVENUE-STEAMER, "DEXTER."

Scale of indicator, 40 pounds per inch.



U. S. REVENUE-STEAMER, "DALLAS."

Scale of indicator, 24 pounds per inch.



ON THE MOMENTS AND REACTIONS OF CONTINUOUS GIRDERS.

By Mansfield Merriman, C. E.,

Instructor in Civil Engineering in the Sheffield Scientific School.

I wish to put here upon record some of the results of my studies on continuous girders, which may, perhaps, prove of interest to practical engineers and bridge designers. In this article I shall take up only the commonest case, viz., girders of a constant moment of inertia, whose spans are all equal, whose supports are upon the same level, and whose ends lie free upon abutments. In designing such a continuous truss it is necessary, in order to compute the maximum strains, to know the moments and reactions at each of the supports for various assigned systems of loading. The calculation of these by algebraic work from the theorem of three moments is long and tedious, particularly when the number of spans is great, or when the truss is to be computed for many different positions of the rolling load. Especially is this true when the loads are considered as concentrated at the panel points of the truss. It is, perhaps, greatly owing to this difficulty of calculation that continuous girders have been heretofore so little used.

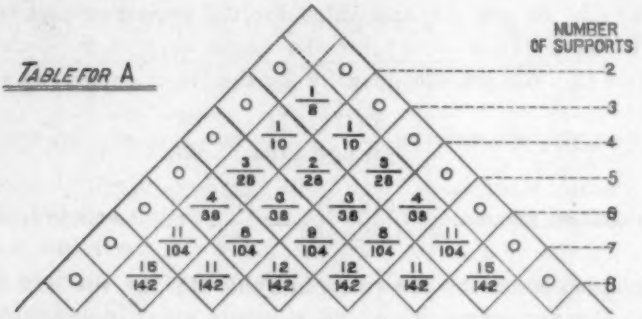
The moments and reactions for girders of equal span follow a law of *diverging values*, by virtue of which they may be presented in triangular tables capable of being extended to include any number of spans. From these tables these quantities at once become known, and the labor of days may thus be reduced to that of a few minutes.

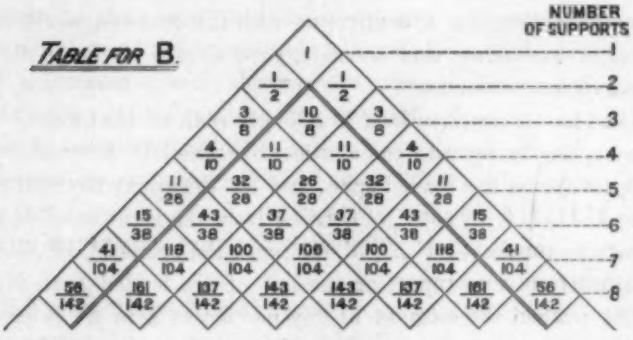
I shall give the moments and reactions for the following cases: I, a uniform load over the whole girder; II, a uniform load in a single span of the girder; III, a single concentrated load in any span of the girder. These three cases can be so combined by the bridge computer as to embrace any required system of loading. The explanation and use of the tables will first be presented, and in a second article a mathematical proof of their accuracy be given.

Case I. *A uniform load over the whole girder.* Let the length of each span be l, and the load per unit of length w. Then at any support,

$$\text{Moment} = A\,wl^2. \quad \text{Reaction} = B\,wl,$$

where A and B are constants given in the triangles below.



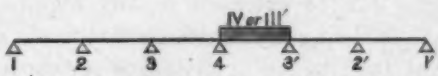


The spaces in these triangles indicate the supports of the girder. Thus, in Table B, the second horizontal line refers to a simple beam of one span, whose reactions at the two supports are $\frac{1}{2}\,wl$ and $\frac{1}{2}\,wl$; the third horizontal line indicates a continuous beam over three supports, where the reactions are $\frac{3}{8}\,wl$, $\frac{10}{8}\,wl$, and $\frac{3}{8}\,wl$ respectively.

These triangles can be extended to any required length by the application of the following law, which obtains in all *oblique columns*. The numerator of the fraction in any space corresponding to an *odd* number of supports is equal to the difference of the preceding and following numerators. The numerator for an *even* number of supports is equal to one-half the difference of those preceding and following, and the same law is true for the denominators. Therefore, to obtain a number when the supports are odd, multiply the last one

by two and subtract the number preceding; when the supports are even add together the two preceding ones. Thus, to get the denominator of the fraction for eight supports in Table A, we have $104+38=142$; to get the numerator for the second support from the left, we have $11+4=15$; for the fourth support, $9+3=12$, or, $8+4=12$. To get the quantity for the fourth support in a girder over nine supports we have $\frac{2\times11+11}{2\times142+104}=\frac{33}{388}$; or, by using the other oblique column, $\frac{2\times12+9}{2\times142+104}=\frac{33}{388}$, the same result. A single exception to this law exists in Table B; the two extreme oblique columns, representing end supports or abutments, although themselves following the above law perfectly, do not when taken in the opposite direction in connection with the other supports or piers. Hence, in extending this triangle, care should be taken to use the longest oblique columns.

Case II. *A uniform load in a single span of the girder.* Let the supports, beginning with the abutment on the left, be numbered 1, 2, 3, etc., as far as the loaded span, and let the spans beginning on the left be I, II, III, IV, etc. Counting from the right hand end let the supports be numbered 1′, 2′, 3′, etc., and the spans I′, II′, etc. Call the moment at any support on the left of the loaded span M, on the right M′; when the moment at any particular support is mentioned it will receive a subscript corresponding to the index of the support, thus, M_3 indicates the moment at the third support from the left, and M'_2, the moment at the second support from the right hand end. In the same way the reactions are called R and R′. The reactions at the supports adjacent to the loaded span will, however, generally be referred to as R_r and R_r'. Thus a girder of six spans with



the fourth span from the right end, loaded, is shown in the figure with the indices corresponding to the above notation.

All the moments will be given by the formulæ,

$$M=\frac{D}{4c}wl^2, \text{ and } M'=\frac{D'}{4c}wl^2,$$

where D, D′, and c are constants to be taken from the following tables:

Loaded Span, counted from Right.	Support counted from Left. 1	2	3	4	5	6	Support counted from Right. 6′	5′	4′	3′	2′	1′	Loaded Span, counted from Left.
D													D′
I′	0	−1	4	−15	56	−209	−209	56	−15	4	−1	0	I
II′	0	3	−12	45	−168	627	627	−168	45	−12	3	0	II
III′	0	−11	44	−165	616			616	−165	44	−11	0	III
IV′	0	41	−164	615					615	−164	41	0	IV
V′	0	−153	612							612	−153	0	V
VI′	0	571	−2284								571	0	VI

To illustrate the use of these tables let us find the moments at the supports in the girder of six spans given above. For the moments on the left of the load, we look out D in the horizontal column III′; since there are six spans, C = −780, Thus

$$M_1 = 0.\quad M_2 = \frac{11}{3120}wl^2.\quad M_3 = -\frac{44}{3120}wl^2.$$

$$M_4 = -\frac{165}{3120}wl^2.$$

For the moments on the right of the load, we look for D′ in the horizontal column IV. Thus

$$M'_1 = 0.\quad M'_2 = \frac{41}{3120}wl^2.\quad M'_3 = \frac{164}{3120}wl^2.$$

Number of Spans.	c
1	1
2	−4
3	15
4	−56
5	209
6	−780
7	2911
8	−10864
9	40545
10	−151316

These tables may be extended to include any required number of spans by the following law, which obtains in all horizontal and vertical columns. Multiply any number by −4, and subtract the preceding one to obtain the next required number; *e. g.*, to obtain the number at the intersection of IV′ and 4, in Table D, we have −4(−164) − 41 = 615, or, −4(−165) − 45 = 615. Also, for D and D′, we have the additional law: To obtain any number, mul-

tiply together the numbers in columns I and 2, and change the sign of the result; thus, $-(-15\times41)=615$.

The reactions due to a uniform load in a single span are all easily obtained from the preceding tables of moments, except those at the supports adjacent to the loaded span. For the reactions at the abutments,

$$R_1=-\frac{M_2}{l}=-\frac{D}{4c}wl, \text{ if the load is not in the first span, and}$$

$$R'_1=-\frac{M'_2}{l}=-\frac{D'}{4c}wl, \text{ if the load is not in the last span.}$$

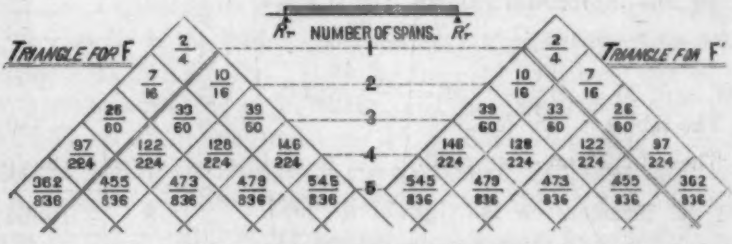
For the reactions at other supports (not adjacent to the load),

$$R=6\frac{M}{l}=\frac{6D}{4c}wl, \text{ and } R'=6\frac{M'}{l}=\frac{6D'}{4c}wl.$$

The reactions at the supports next to the loaded span will be given by the expressions,

$$R_2=Fwl, \text{ and } R_2'=F'wl,$$

in connection with the following tables; where the spaces indicate *spans;*



thus, if a girder of two spans have a uniform load in the first, we have at once,

$$F=\frac{7}{16} \text{ and } F'=\frac{10}{16}$$

The numbers in this triangle follow (numerically in the oblique columns) the same law as D; four times any number minus the preceding one being equal to the next following one. The first oblique column in F, and the last in F', representing abutments, vary from the law when taken in connection with the other columns, although they themselves follow it perfectly.

For example, let us find the reactions due to the uniform load in the girder of six spans given above; we have $R_1=-\frac{D_1}{4c}wl=-\frac{11}{3120}wl$.

$R_2 = \frac{6D_2}{4c} wl = \frac{66}{3120} wl$, etc.; also, $R_4 = F wl$, where F is found by the law from the table, or $F = \frac{4\times479 - 146}{4\times836 - 224} = \frac{1770}{3120}$, and similarly for F', $\frac{4\times473 - 128}{4\times836 - 224} = \frac{1764}{3120}$. Hence, from the above formulæ, the reactions for that case are,

$$R_1 = -\frac{11}{3120} wl. \quad R_2 = \frac{66}{3120} wl. \quad R_3 = -\frac{264}{3120} wl. \quad R_4 = \frac{1770}{3120} wl.$$

$$R'_1 = \frac{41}{3120} wl. \quad R'_2 = -\frac{246}{3120} wl. \quad R'_3 = \frac{1764}{3120} wl.$$

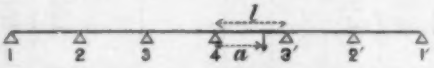
Case III. *A single concentrated load in any span of the girder.* In addition to the notation previously employed I call the concentrated load P, and its distance from the nearest left hand support *a*. The quantity, $\frac{a}{l}$, is of very frequent occurrence and is represented by *k*.

As in the previous case all the moments will be given by

$$M = \frac{G}{c} Pl, \text{ and } M' = \frac{G'}{c} Pl.$$

The tables on the following page give G and G';

These tables are used exactly like those in the previous case; for illustration let us take a girder of six spans, with a load in IV or



III'. Looking for G in the horizontal column III' we have

$M_1 = 0$. $M_2 = \frac{Pl}{780}(26k - 45k^2 + 19k^3)$. $M_3 = -4M_2$. $M_4 = 15M_2$.

Looking for G', in the horizontal column IV, we get

$M'_1 = 0$. $M'_2 = -\frac{Pl}{780}(26k + 45k^2 - 71k^3)$. $M'_3 = -4M'_2$.

Substituting in these expressions the numerical values of $k = \frac{a}{l}$, corresponding to the panel distances of the truss in hand, the

G	SUPPORT COUNTED FROM LEFT. 1	2	3	4	5	6
I′	0	$-(2k-3k^2+k^3)$	$4(2k-3k^2+k^3)$	$-15(2k-3k^2+k^3)$	$56(2k-3k^2+k^3)$	$-209(2k-3k^2+k^3)$
II′	0	$(7k-12k^2+5k^3)$	$-4(7k-12k^2+5k^3$	$15(7k-12k^2+5k^3)$	$-56(7k-12k^2+5k^3)$	$209(7k-12k^2+5k^3)$
III′	0	$-(26k-45k^2+19k^3)$	$4(26-45k^2+19k^3)$	$-15(26k-45k^2+19k^3)$		
IV′	0	$(97k-168k^2+71k^3)$	$-4(97k-168k^2+71k^3)$			
V′	0	$-(362k-627k^2+265k^3)$				
VI′	0	Etc.				

LOADED SPAN, COUNTED FROM RIGHT

6′	5′	4′	3′	SUPPORT COUNTED FROM RIGHT. 2′	1′	G′
$-209(k-k^3)$	$56(k-k^3)$	$-15(k-k^3)$	$4(k-k^3)$	$-(k-k^3)$	0	I
$209(2k+3k^2-5k^3)$	$-56(2k+3k^2-5k^3)$	$15(2k+3k^2-5k^3)$	$-4(2k+3k^2-5k^3)$	$(2k+3k^2-5k^3)$	0	II
		$-15(7k+12k^2-19k^3)$	$4(7k+12k^2-19k^3)$	$-(7k+12k^2-19k^3)$	0	III
			$-4(26k+45k^2-71k^3)$	$(26k+45k^2-71k^3)$	0	IV
				$-(97k+168k^2-265k^3)$	0	V
				Etc.	0	VI

LOADED SPAN, COUNTED FROM LEFT

moments due to every position of the rolling load in this span become known.

The law for the extension of these tables is apparent upon inspection. The coefficients of k, k^2, and k^3 increase vertically by the law of multiplying each number by four and subtracting the preceding one. The coefficients of the parentheses increase horizontally by the same law, and their signs alternate.

The reactions become known by formulæ and tables similar to those of the preceding case. For the reactions at the abutments,

$$R_1 = -\frac{M_2}{l} = -\frac{G}{c}P, \text{ and } R'_1 = -\frac{G'}{c}P.$$

For all the other reactions except those at the supports adjacent to the loaded span,

$$R = 6\frac{M}{l} = 6P\frac{G}{c}, \text{ and } R' = 6P\frac{G'}{c}.$$

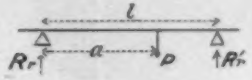
The reactions at the supports adjacent to the loaded span would be best presented to the eye by triangles similar to those used in the last case, but for convenience in printing they will be given in tables like those used for the moments.

The spaces in these tables represent spans; by following the oblique lines the values may be taken out as in the triangles; thus all the quantities beginning with $\frac{P}{56}$ belong to a girder of four spans.

Or, without considering the number of spans, the reactions may be determined by the number of the span counted from each end. Thus, if a load be on the second span from the left and fourth from the right, the reactions adjacent to the loaded span are found in the spaces at the intersection of II and IV′.

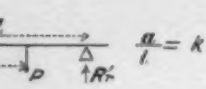
These tables follow, in the horizontal and vertical columns, the law of multiplying each number by four and subtracting the preceding one to obtain the next following number. As before it is to be noticed that the first vertical column for R and the first horizontal column for R′, representing the reactions at the abutments, do not conform to the law when taken in connection with the others, although they themselves follow it exactly.

R_r	LOADED SPAN COUNTED FROM LEFT HAND. I	II	III
LOADED SPAN COUNTED FROM RIGHT. I′	$P\,(1-k)$	$\frac{P}{4}(4-6k^2+2k^3)$	$\frac{P}{15}(15+3k-27k^2+9k^3)$
II′	$\frac{P}{4}(4-5k+k^3)$	$\frac{P}{15}(15-3k-27k^2+15k^3)$	$\frac{P}{56}(56-120k^2+64k^3)$
III′	$\frac{P}{15}(15-19k+4k^3)$	$\frac{P}{56}(56-12k-102k^2+58k^3)$	$\frac{P}{209}(209-3k-453k^2+$
IV′	$\frac{P}{56}(56-71k+15k^3)$	$\frac{P}{209}(209-45k-381k^2+217k^3)$	$\frac{P}{780}(780-12k-1692k^2$
V′	$\frac{P}{209}(209-265k+56k^3)$	$\frac{P}{780}(780-168k-1422k^2+810k^3)$	



R'_r	LOADED SPAN COUNTED FROM LEFT HAND. I	II	III
LOADED SPAN COUNTED FROM RIGHT. I′	Pk	$\frac{P}{4}(2k+3k^2-k^3)$	$\frac{P}{15}(7k+12k^2-4k^3)$
II′	$\frac{P}{4}(6k-2k^3)$	$\frac{P}{15}(12k+18k^2-15k^3)$	$\frac{P}{56}(42k+72k^2-58k^3)$
III′	$\frac{P}{15}(24k-9k^3)$	$\frac{P}{56}(48k+72k^2-64k^3)$	$\frac{P}{209}(168k+288k^2-247$
IV′	$\frac{P}{56}(90k-34k^3)$	$\frac{P}{209}(180k+270k^2-241k^3)$	
V′	$\frac{P}{209}(336k-127k^3)$		

III	IV	V
$-27k^2+9k^3)$	$\frac{P}{56}(56+12k-102k^2+34k^3)$	$\frac{P}{209}(209+45k-381k^2+127k^3)$
$k^2+64k^3)$	$\frac{P}{209}(209+3k-453k^2+241k^3)$	$\frac{P}{780}(780+12k-1692k^2+900k^3)$
$3k-453k^2+247k^3)$	$\frac{P}{780}(780-1710k^2+930k^3)$	
$2k-1692k^2+924k^3)$		



$\frac{a}{l}=k$

III	IV	V
$^2-4k^3)$	$\frac{P}{56}(26k+45k^2-15k^3)$	$\frac{P}{209}(97k+168k^2-56k^3)$
$k^2-58k^3)$	$\frac{P}{209}(156k+270k^2-217k^3)$	
$288k^2-247k^3)$		

	q
q_1	α
q_2	β
q_3	$4\beta - \alpha$
q_4	$15\beta - 4\alpha$
q_5	$56\beta - 15\alpha$
q_6	$209\beta - 56\alpha$
q_7	$780\beta - 209\alpha$
q_8	$2911\beta - 780\alpha$
q_9	$10864\beta - 2911\alpha$
q_{10}	$40545\beta - 10864\alpha$
	Etc.

If it were desired to use these tables for the calculation of a continuous girder of a great number of spans, say twenty, it would by no means be necessary to compute all the intermediate values to obtain the quantities for that case. The extension of a single oblique column, or most two, will always be sufficient, in connection with the following table of multipliers. If a series of numbers follow a law such that each one is equal to four times the preceding, minus the next preceding, they will be represented by the following table, where α and β are any two such numbers, and q_1, q_2, q_3, etc., the successive numbers beginning with α. This table may be made out once for all, since the co-efficients of α and β follow the above law. For instance: To obtain from table F the moment at support 3, due to a uniform load in span III, for a girder of twenty spans, we have $\alpha = 39$, $\beta = 128$ for the numerators, and $\alpha = 60$, $\beta = 224$ for the denominators, and the corresponding quantities will be determined by substituting these values in q_{19}. Tables A and B may be extended in this way, since the quantities corresponding to even numbers of spans follow this same law, as also do the odd spans.

I might also give tables like the above which would give the moments and reactions due to a uniform load over a part only of a single span. Should they be required they can be obtained in every case from the formulæ for a single concentrated load by putting P equal to wda, and integrating the expressions between the desired limits. Tables following the same law of diverging values could also be given for the inflection points, and the maximum deflection in every span, but would be of very little practical value. The moments and reactions alone are sufficient to fully compute any truss. The former divided by the depth of the truss gives the chord strains over the supports; the latter determine the shearing force at every cross section. From these the strains in all the other members may be easily found either by algebraic or graphical methods for the proper cases of loading.

In the next number of this JOURNAL I propose to give a strict mathematical demonstration that the above laws and formulæ hold true for all continuous girders of the class considered, and by which anyone may test the accuracy of the tables here presented. I shall also investigate and present simple formulæ and tables for the case where the two end spans are different in length from the other spans, the ends being either free upon abutments or firmly fastened, so that the tangent at that point is always horizontal.

THE NEW PAVILION WARD OF THE PRESBYTERIAN HOSPITAL OF PHILADELPHIA.

BY JOSEPH M. WILSON, C. E., Engineer and Architect.

The Presbyterian Hospital of Philadelphia has now nearly completed a new Surgical Pavilion Ward on its grounds at Thirty-ninth Street and Powelton Avenue, and as the plan and arrangement are a considerable departure from the old established and time-honored principles of hospital construction, a short description may be of interest.

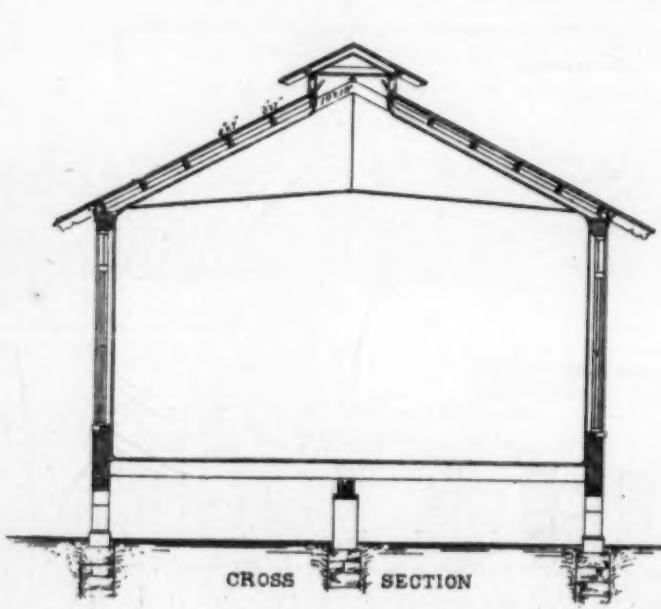
The principles of the arrangement are based on those of the United States Temporary Military Hospitals erected during the late war, and afterwards extensively adopted in Germany during the Franco-German War, and also to a greater or less extent, made use of in some of the later European permanent constructions.

The building, as shown by the accompanying plan, consists of only one story, and is comprised in a rectangular space of 32 feet by 143 feet, its position lengthwise being nearly north and south. It contains the following apartments: A sitting-room of 30 by 16 feet at the south end, communicating directly with a ward-room of 30 by 88 feet, the latter having a capacity of 28 beds. From the north end of the ward-room a hall of 6 feet in width connects with an entrance from the street at the north end of the building. On the west side of this hall are arranged the operating room, 11½ by 16 feet, and the nurses' room 11½ by 14 feet, the latter having a large linen closet 11½ by 5 feet attached to it. On the east side are the baths and

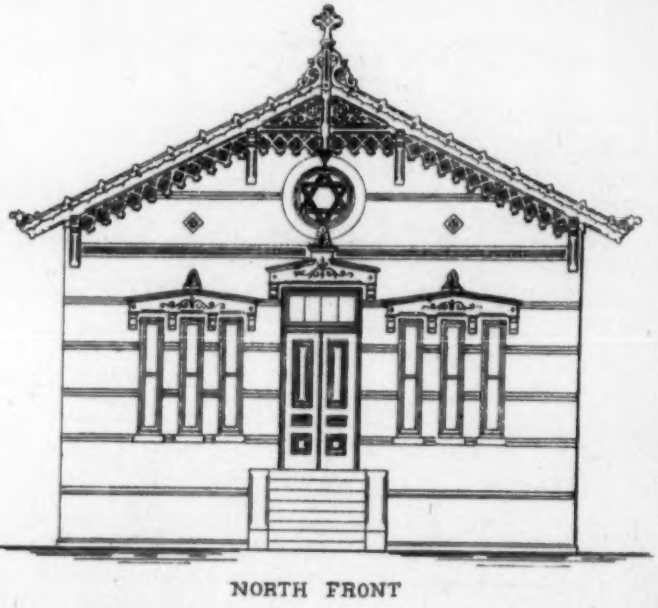
lavatories and water-closets, and a special diet kitchen of 11½ by 10 feet.

The foundations of the building are of stone. The floor is raised to a level of 5 feet above the ground, and the space underneath left open to the free circulation of air by means of arches in the brick walls along the sides of the building, the area of ground contained within being covered with a good asphalte pavement, so as to prevent any moisture arising from it. The ground around the building is well sloped off so as to drain all water away from it. The exterior walls are of brick, 13 inches thick, and built hollow.

The north, or street entrance, is of pressed brick, with courses of colored brick and Ohio stone dressings, the entrance steps being of granite. Particular care has been taken in building the walls that no opportunity shall be afforded for moisture to get through from the outer to the inner portions of the wall. Between every window, and near the level of the floor, small openings are made from the exterior to the inner air space of the brick walls, with little iron doors to them that may be opened or closed at pleasure. These openings all have permanent wire screens to prevent entrance of vermin. At the top of the wall the air space communicates with the space between the roof sheathing and plastering by a series of openings corresponding with the lower ones. The walls are 15 feet high in the clear from top of floor. The floors are laid with best quality Carolina pine boards, in very narrow widths, tongued and grooved, and put together with white lead, so as to make a thoroughly water-tight job, the spaces between the joists underneath being boxed and filled in with mortar concrete close up to the flooring. The windows are made of double glass, with an air space of ½ inch between them. Each window has an upper and lower sash, that may be raised or lowered, and a swinging transome above. The window sills are of slate. Under each window in the inner face of the wall an opening is made communicating with the inner air space of brick work and fitted with a register that may be opened or shut as desired. The ward room ceiling is finished off on the slope of the roof and is provided with a ridge ventilation for its whole length. Small openings are made up under the ridge ventilators into the space between the plaster and sheathing about every 12 feet, so as to allow of circulation of air through the entire air spaces of wall from the previously mentioned openings below. The ceilings of the other rooms are



CROSS SECTION



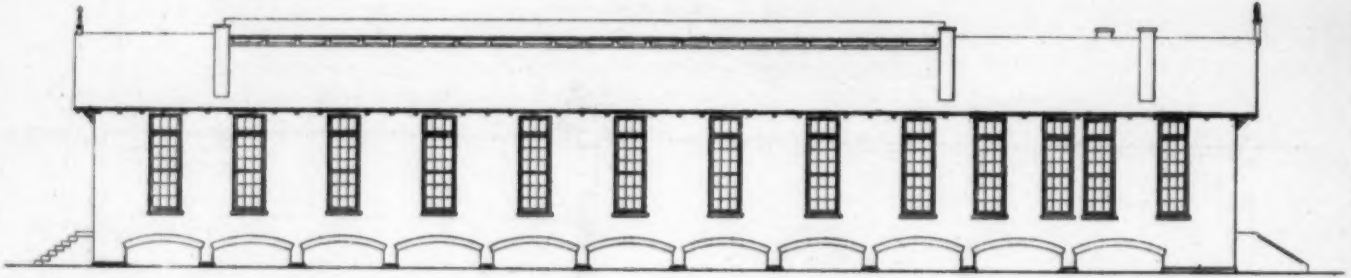
NORTH FRONT

ONE STORY PAVILION HOSPITAL WARD

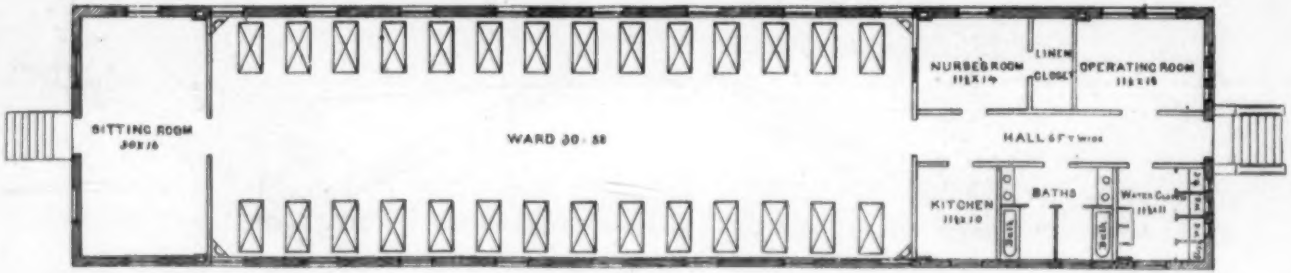
FOR THE

PRESBYTERIAN HOSPITAL WEST PHILAD^{a}

Jno. H. Nelson
Engineer & Architect



LONGITUDINAL ELEVATION.



MAIN FLOOR

Photo-lith. Printed by J.H. Bufford, 510 Sansom St. Phila.a

horizontal and at a height of 15 feet from the floor. All of the inside doors except the one to the water-closet have transomes, swung on centres.

The plastering is in three coats, troweled down to a thoroughly smooth hard finish, and as soon as perfectly dry in every respect it will be painted.

The roof is covered with slate.

In finishing up the interior work especial care has been taken to make everything as plain as possible; no mouldings, no grooves or ledges to catch and hold dust, but every necessary projection rounded off and made smooth. The doors are not paneled but are made perfectly plain, of tongued and grooved boards in two thicknesses, without beads. The plastering has been rounded at the ceilings, the windows, the angles of the rooms, etc., there being no sharp corners. It is finished at the bottom next to the floor in Portland cement, and there are no washboards. All of the inside woodwork is rubbed down smooth and finished with linseed oil and shellac. The floor is oiled in two coats linseed oil well rubbed in.

A small range is placed in the special diet kitchen, and has connected with it a large circulating galvanized iron boiler to supply bath tubs with hot water.

The building is heated by a hot water circulating apparatus.

A small cellar is placed in the southeast corner of the building, under the sitting-room, and also one in the northwest corner under the operating room, each being 16 feet square. In each of them a boiler will be placed, with radiating pipes carried through the different rooms. Four open grates are placed in the four corners of the main ward, entirely for ventilating purposes.

The plans were prepared by the Engineer and Architect, under the direction of the Building Committee, the gentlemen who composed it being indefatigable and enthusiastic on the system adopted, and any merits the plan may possess are justly due to them.

Chemistry, Physics, Technology, Etc.

NEW PROCESSES IN PROXIMATE GAS-ANALYSIS.

By Professor Henry Wurtz, of New York.

[*Communicated in part, with Experimental Illustrations, to the American Gas-Light Association, October* 22, 1874.]

(Continued from Volume lxix, page 155.)

The soda-pencils are cracked up, a few at a time, by gentle blows in a mortar, to lengths of from ·5 to ·7 inch. This is very rapidly and easily effected; but still a film of moisture is absorbed; and I have found that desiccated gas will then take up from it a trace of water. The precaution is therefore taken to append a small CaCl tube to the second of the two, M. This may be avoided if the Preparatory Train, Fig. 2, be employed to dry out these soda-tubes, before their initial weighing.

The Meter and the Measurement Thereby.—This most essential operation of all, is effected with every precaution to insure known conditions of the residual gas. In the case represented in Fig. 1, it is to be understood that a dry meter is used to measure the gas as absolutely freed from moisture, and at, or as close as possible to, the temperature of melting ice. Within N, filled with cracked ice, is coiled some feet of rubber tubing—well *glycerated* internally—and the meter is enclosed—leaving the dial exposed—in an outer casing, not here shown, filled with feathers, or better, with *ice*. In an emergency, muffling the meter in blankets has been resorted to.

The meters used must of course be most carefully tested and their average errors determined and taken note of. Space cannot, unfortunately, be here spared to explain the modes of effecting this. As it may often be necessary to use wet meters, like those usually found in photometric rooms, I have represented in Fig. 4 a modified mode of measurement, which admits of such use. Here also the whole meter, except the dial, ought to be protected, as before, from external warmth.

It will be readily understood that when the photometric meter—which usually registers but four feet in one revolution—must be employed, appropriate measures must be taken to mark, or to verify in some sure way, the number of revolutions, when these are desired, or are likely to exceed two revolutions in all. In Fig. 1, as I ought further to explain in this place, the eduction-tube O, which is the prolongation of the coil in N, passes to the inlet-aperture of a *dry* meter, and not, as in Fig. 4 below, to the rear of a wet-meter drum.

II. Of the Preparatory Train. (Fig. 2.)

This is employed in the initial drying-out of the apparatus, preparatory to the first weighings; and also for the final completing of the separation preparatory to the last weighings; in the latter case, by the distilling or transferring over, in a current of pure dry gas, of the liquids that condense, by mere refrigeration and adhesion, in the first tubes.

It is made up as follows: Stop cock A, in an induction-tube from any service-pipe bringing street-gas; test-tube B with inlet-tube passing to its bottom, which contains a strip of turmeric paper, to indicate (qualitatively) ammonia; two U-tubes C and D, containing respectively granulated fused bisulphate of potash and granulated blue vitriol; a second test-tube E, containing slips of both turmeric and lead-paper, to demonstrate the complete removal by D and E of the HS and NH^3 (the latter by comparison with the turmeric paper in B); a CaCl tube F; and a sodic hydrate tube H (of large dimensions, as shown, in cases where the street-gas, through iron-purification or otherwise, contains very much CO^2). [B, in this train, is not at all essential.]

In this figure the Preparatory Train is represented as attached to the first compound member (marked A′) of the train for analysis of purified gas, shown in Fig. 4. In Fig. 3, H represents the final member of the preparatory train; showing its connection with the train in Fig. 1, during the distillation preparatory to the final weighings.

It may be stated that this preparatory train being required only to furnish a current of gas free from moisture and impurities, it is obvious that the current that issues from one analytical train while in operation, is suitable for the preparation, for either initial or final weighings, of another analytical train, and that this circumstance

FIG. 2.

SUPPLEMENTARY OR PREPARATORY TRAIN; BOTH FOR PRELIMINARY PREPARATION OF THE TRAINS FOR ANALYSIS, AND FOR COMPLETION OF THE PROCESSES THEREIN.

will at times be available, and lead to saving of trouble in transportation and erection of apparatus.

Another important point of practice with the preparatory train, demands a few words. Its union with the analytical train represented in Fig. 1, makes a long and very tortuous passage for the gas, which necessitates an important *pressure* to force a rate of flow sufficient for rapid work. This is very liable to cause difficulty, with street-gas, particularly during the midday hours. It will therefore often be advisable to arrange so as to conduct preparatory operations during the night hours. Cases occur in which special expedients may be necessary to procure a sufficient flow. A small gas-holder, when available, may be used. The pressure in the mains between the exhauster and the purifiers will always be ample to force one or even two cubic feet per hour through almost any length of (unobstructed) train; but in this case it must be remembered that the preparatory train should possess an extra size and power, and be properly proportioned, to take out the large proportion of impurities present; for if a preparatory train left working with an analytical train overnight should become fouled, of course the whole apparatus would be liable to be rendered useless, and the whole time and labor be lost.

It may be scarcely necessary to suggest that for these preparatory operations, coal-gas is used only for convenience, With a holder, or an aspirator, a stream of *air*, similarly freed from water, ammonia, carbonic acid, etc., is generally equally applicable, and when the pressure has to be assisted, we may in most cases just as well use air, if we have the appliances.

III. Of the General Manipulations with Crude Coal-Gas.

In addition to the details which have been given when describing singly the members of the train in Fig. 1, further explanations are needed, especially with regard to the application of the preparatory train thereto. In the preliminary preparations for the *initial* weighings, it it unnecessary, with the arrangement as here represented, to attach more than the first four pieces, to and including the bisulphate tube G, for reasons which will be obvious without explanation. Some five or six cubic feet of gas transmitted from a preparatory train, will dry out these first four members sufficiently to allow of correct weighing. This will be accomplished by setting and keeping the apparatus at work during one night, say from 5 P. M. till 8 A. M.,

or 15 hours, at the rate of about 0·3 or 0·4 foot per hour. The rate of flow is readily regulated by a few observations, of ten minutes each, of a meter at the tail of any train. A little practice enables the rate to be judged of closely enough, by the size of the flame burning from a small straight glass tube at the tail of the apparatus, as shown in Fig. 4.

The preparation for the final weighings is here the important part, and indeed the only troublesome part of this analysis. Fig. 3 repre-

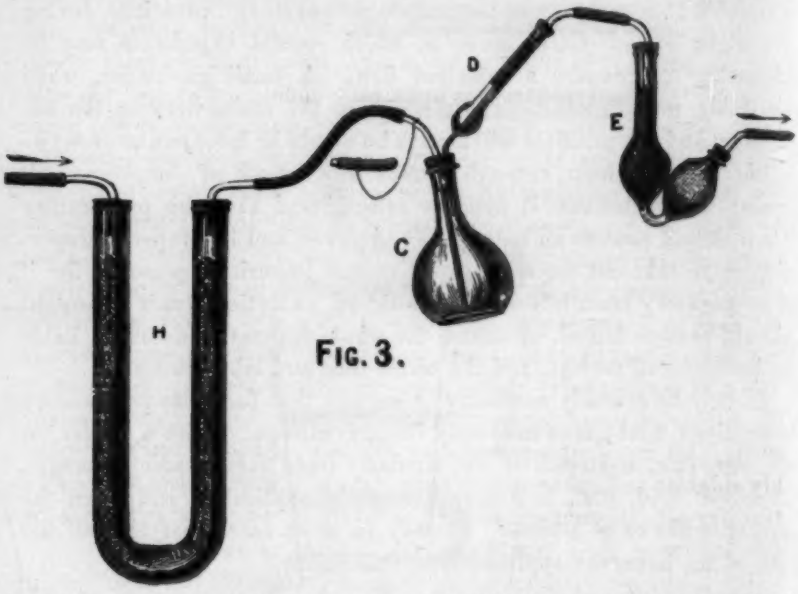


FIG. 3.

Supplementary Arrangement for Completion of Process in the Train, shown by Fig. 1.

sents, as aforesaid, the mode of attaching the preparatory train to Fig. 1, for this final operation, or rather succession of operations. D here represents a new tube introduced at this time, which is an ordinary form of CaCl tube, but having its smaller extremity bent at an obtuse angle, as shown, and which contains near its upper end a slip of turmeric paper, and has, moreover, running through it from end to end, and projecting an inch at each end, a *small flexible copper wire;* the object of which latter is to clear a passage through the crystals of naphthaline which condense in this tube at a subsequent stage of operations.*

* This wire should have been shown more distinctly in the cut, but this is only one of several unfortunate defects in these cuts.—H. W.

After this disposition of the apparatus has been made—D having been of course *weighed* with its appendages, and the jar of ice N (which is no longer of use) removed, the meter being connected directly with M—the first step is to distill over, at a very low temperature (unless saving of time is important, at ordinary temperatures) in the current of gas from the preparatory train—which generally in this case may flow even as rapidly as two feet per hour—all the volatile ammonic carbonate and sulphohydrate that has condensed in the flask C and cotton tubes E and F. The volume of gas required to effect this may be double (or even more) that from which the liquid was condensed. It ought to have been stated that the total amount of crude gas analyzed by this apparatus should not exceed ten cubic feet. This volume is within the limits of manageability, but generally somewhat less is probably advisable. With a rapid current of gas, this complete transfer of the volatile ammonia-compounds will be found to have been effected during 15 or 18 hours; but sometimes more time is required; and it is better to allow 24 hours for this part of the process. If an attempt to hasten it is made, by immersion of the flask in warm water, constant watching is necessary, as naphthaline then enters upon the scene, and may at once clog up all passage. The complete transfer of the ammonia is indicated by the return of the slip of turmeric-paper to its natural color. As, in my experience so far, this liquid *always* contains chloride of ammonium, and possibly sulphite and other non-volatile ammonia salts, those who wish to transfer *all* the ammonia to the bisulphate-tube G, must introduce into the flask a weighed quantity of dry hydrate of soda.

When the ammonia-transfer has been completed, the flask C is immersed—the gas-current being continued—in water sufficiently hot to volatilize the naphthaline, which will condense in crystalline form, together with water, in the tube D. The wire running through D now comes into play; and, in fact, without it, naphthaline would here become as great a cause of difficulty as it often does in the distribution of coal gas. When clogging occurs, the gas-current is stopped, the rubber connector between D and E detached, and the wire moved up and down or twisted round. With careful management, two hours work and some two feet of gas from the preparatory train, will suffice to transfer the naphthaline to D, which is then detached and weighed again. To remove the intermixed water from the naphthaline, the lower end of D is stopped, the cork and tube removed from the upper

end, the wire coiled within, and this upper end connected by a wide short rubber-connector with the open end of a test tube containing some granulated CaCl. When dry, the cork and tube are restored, the stopper removed, and the weight again ascertained; the variation now from the first weight is the naphthaline, so far as it can be saved by this mode; which of course is imperfect, but is the best that I have so far succeeded in devising.*

The flask C, still containing tar and water is then removed likewise from the arrangement—the stoppers DD (Fig. 1.) being applied—and then H of the preparatory train is connected directly with the first cotton-tube E; the gas-flow being resumed. Some five feet more of dry gas may be now required to transfer all the moisture to the CaCl tube between G and H (omitted from the cut.) The water and tar in the flask C must be separated by careful distillation at a very moderate temperature, and in estimating the weight of the residual tar, account must be taken of the sodic hydrate that was added, as above, to eliminate the fixed ammonia.

The point at which the whole train becomes dry and ready for the final weighings, is readily perceived by a practiced eye. One indication is a faint superficial whitening of some unaltered blue granules (if any) of cupric sulphate in the tube HJ. Several other indications might also be cited.

IV. Of the General Manipulations with Purified Coal-Gas.

Fig. 4 represents a very complete train for this purpose. As the suspended matter here is absent or trifling in amount, and the ammonia usually very small, A represents a combined arrangement for taking up both these. The first or right hand U-tube is loosely filled with cotton, the second one with granular bisulphate. E contains two slips, of turmeric and red litmus paper, to verify the perfect efficiency of the bisulphate. F contains granulated cupric sulphate crystals. G is CaCl. H is sodic hydrate, with a small CaCl-tube appended. The arrangement KL, for determining oxygen, requires special explanation. K contains glass beads or broken-up glass rod, wet with a concentrated solution of pyrogallol in previously-boiled water. L contains CaCl. As, in order that the pyrogallol should

* Since the above was first presented to the Gas-light Association, I have discovered that very appreciable additional traces of naphthaline condense, and remain throughout the final desiccation, in the cotton-tubes E and F, and have therefore been rated as solid matter mechanically suspended.—H. W.

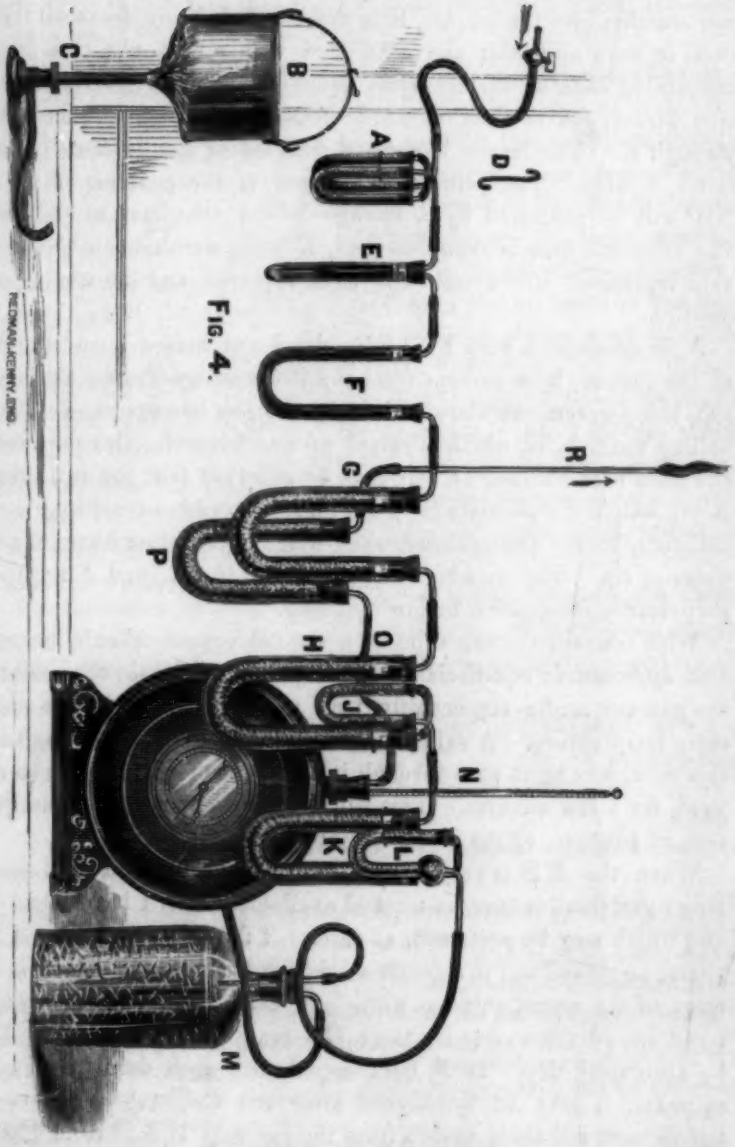


Fig. 4.

Trains for the Analysis of Purified Coal-Gas, Etc.

take up the oxygen, there must be an alkali present, the following special course is adopted for preparing KL for initial weighing and introduction into the train. K is immersed, L being detached for the time, in snow and salt; and connected with a flask like C in Fig. 1, containing some of the strongest liquid ammonia. A current of common street gas is then directed first into the ammonia flask, then through K. The former is warmed, and the as gas, it issues from the latter, lighted. The point of saturation of the contents of K with NH^3 will be indicated by a change in the character of the flame. The ammonia-flask is then detached, K being simultaneously—to prevent ingress of air—attached to J, L replaced, and the whole put in position.

A, in connection with E, is also dried out before initial weighing of the former, by a current from the Preparatory Train; this operation being greatly accelerated in this case, by immersion of A in the boiling water in B, which is raised up and hung, for this purpose, on the little wire pothook D. It is to be observed that the two tubes in A are weighed separately, and not together; and to avoid hygroscopic moisture, cooled and enclosed while weighing, in close boxes of sheet-brass or tin. The members of this train G, H, and P require no preparatory desiccation before weighing.

With reference to the tube P, a special remark should be made. The *hygrometric* equilibria of the cupric sulphate in the aerial and the gaseous media respectively, may appreciably vary, even at the same temperature. A safe plan, therefore, before initial weighing of this tube, will be to pass through it a current of the gas to be analyzed, for a few minutes. This will serve also as a useful qualitative test, in advance, of the amount of H S present.

When the H S is very minute, as it should be in a well-purified street-gas, there is another method available, which I have often used, and which may be preferred, as surer. I find if the granulated blue-vitriol be spread out in a gentle sand-bath heat, for some days, it loses most of its water, turning white and chalk-like, without falling to powder, and will now still absorb H S readily, even though the latter be absolutely dry. If F be charged with such dehydrated cupric sulphate, it may be introduced after the CaCl-tube G, instead of before, and will there absorb from the gas only H S. If it has lost as much as three-fifths of its water, it will not impart any moisture to the gas at ordinary temperatures.

(To be Continued.)

FORMULÆ FOR THE APPARENT SPECIFIC HEAT OF SATURATED VAPORS.*

By P. P. POINIER, Post Graduate Course, Stev. Ins. Tech., Hoboken.

It has long been admitted by engineers that when high rates of expansion are used the steam jacket effects a saving of fuel. The most plausible theory advanced to account for this saving is, that the hot steam in the jacket prevents in a measure that cooling of the cylinder indirectly due to the work performed. The details of this theory are of course familiar to all engineers, the most important supposition being, that just enough heat is furnished by the jacket to prevent any of the expanding steam from liquefying, and the argument alleged in its support, that wet steam is a very good, while dry steam is a very poor conductor of heat.

Whatever may be the defects of this theory, it seems to be the most generally accepted one; in comparing, therefore, the experimental saving with that deduced from this theory, the quantity to be calculated is the amount of heat necessary to prevent a certain quantity of saturated steam, expanding between given limits, from liquefaction.

The fundamental fact, that, steam expanding in a cylinder without receiving or emitting heat would undergo liquefaction in consequence of the external work performed was first definitely signaled by Professor Rankine.

In a paper read before the Royal Society of Edinburgh, on the 4th of Feb., 1850, he gave the following formula for the apparent specific heat of saturated vapor:

$$K_s = \frac{1}{CnM}\left(\frac{1}{N}+1-\frac{\beta^1}{\tau}-\frac{2V^1}{\tau^2}\right) \text{ numbered } \quad (30)$$

in which C denotes the absolute temperature of melting ice, *i. e.*, 273°

[*We have received the accompanying paper from Prof. Thurston with a memorandum to the effect that the treatment so neatly carried out by the author, gives the reader of Thermo-dynamics a new and very convenient expression which may be used in deducing the amount and effect of condensation within the steam cylinder due to the expenditure of energy. This, like the paper of Mr. Henderson, Class of '74, is supplementary to a portion of the work of Rankine and Clausius, and not merely a new rendering of old methods.

The value of such new conceptions and methods in the science of Thermo-dynamics is a sufficient excuse for its publication, and one which will be appreciated even by non-mathematical readers.—ED.]

Cent., 493·2° Fahr., n the number of molecules of the substance which occupy unity of volume under standard pressure, when in the state of perfect gas; M the "total mass of one molecule;" N such a quantity that $\frac{1}{CnMN} = \mathfrak{R}$, the actual specific heat of the substance in the state of perfect gas; and β^1 and γ^1 constants entering the expression,

$$\log_e P = \alpha - \frac{\beta^1}{\tau} - \frac{\gamma^1}{\tau^2}.$$

τ being the absolute temperature on the air thermometer.

Immediately afterward he wrote:

"For the vapors of which the properties are known, the negative terms of this expression exceed the positive, at all ordinary temperatures, so that the kind of apparent specific heat now under consideration is a negative quantity."*

While this formula is less adapted to computation than some that have since been proposed, it is still of historic interest as having been the original expression of an important discovery.

A month later Clausius published† his first *memoire* on the "Moving Force of Heat." Applying first the law of Mayer and Joule, and then the principle of Carnot, he established the two following equations:

$$\frac{dr}{d\tau} + C - h = A(s - \sigma)\frac{dp}{d\tau} \qquad \text{numbered III.}$$

$$\text{and } \frac{dr}{d\tau} + C - h = \frac{r}{\tau} \qquad \text{numbered (32).}$$

In these equations r represents the latent heat of evaporation of the substance; C the specific heat of the liquid; h the specific heat of the saturated vapor, corresponding to Rankine's K.; A the thermal equivalent of energy, that is 1·424 in French, or 1·772 in English units; p the normal pressure per unit of surface, and $(s - \sigma)$ the increase of volume accompanying evaporation, which, in the case of water, may without sensible error be written v, the total variable volume.

Equation III embodies a method which is suggested by an equation in Rankine's Steam Engine and other Prime Movers, although

*Trans. Roy. Soc. Edin. vol. xx, p. 171.

†Poggendorff's Annalen, 1850, series iii, vol. xix, p. 368.

no direct reference is there made to it.* The simplest method, however, of calculating h or K_n when the limits are given as temperatures, is derived by means of the principle of Carnot, for in a "Carnot's cycle."

$$Q = \tau \frac{dQ}{d\tau},$$

and also when a liquid is evaporated at constant temperatures the whole of the transfer of heat takes place at this temperature, and the pressure also remains constant, so that

$$\frac{dQ}{d\tau} = Av\frac{dp}{d\tau},$$

but in general

$$\triangle Q = A(\triangle I + \triangle W),$$

I denoting internal energy, and W external work performed, so that

$$\int_{\tau_0}^{\tau_1} v\frac{dp}{d\tau}d\tau = \int_{\tau_0}^{\tau_1} \frac{I + W}{\tau}d\tau.$$

In the case of water I + W has been determined by Regnault experimentally, the result being

$$A(I+W) = 606{\cdot}5 - 0{\cdot}695T - 0{\cdot}00002T^2 - 0{\cdot}000003T^3.$$

To simplify this expression Clausius has proposed writing

$$A(I+W) = 607 - 0{\cdot}708T,$$

which would give

$$A\int_{\tau_0}^{\tau_1} v\frac{dp}{d\tau}d\tau = 607 \log_e \frac{\tau_1}{\tau_0} - {\cdot}708(\tau_1 - \tau_0) + 193{\cdot}3 \log_e \frac{\tau_1}{\tau_0}$$

$$= 800{\cdot}3 \log_e \frac{\tau_1}{\tau_0} - {\cdot}708(\tau_1 - \tau_0).$$

Solving now equation III, for h we find

$$h = \frac{dr}{d\tau} + c - \frac{A(I+W)}{\tau},$$

which, recollecting that $A(I+W) = r$ when τ is constant, we see is identical with (32) so that finally

$$\int_{\tau_0}^{\tau_1} h d\tau = -800{\cdot}3 \log_e \frac{\tau_1}{\tau_0} + 1{\cdot}013(\tau_1 - \tau_0),$$

*Rankine's Steam Engine and other Prime Movers, p. 400, eq. 12.

and when common logarithms are used,

$$\int_{\tau_0}^{\tau_1} h d\tau = -1842{\cdot}8 \log_e \frac{\tau_1}{\tau_0} + 1{\cdot}013(\tau_1 - \tau_0)$$

This quantity $\int_{\tau_0}^{\tau_1} h d\tau$ represents then the quantity of heat which must be transferred, in order that the temperature of a unit of weight of saturative steam may be changed from the temperature τ_0 to τ_1 cent. degrees. It includes not only the heat equivalent of the variation in internal energy, but that of the external work while the saturated state is continually maintained.

For absolute temperatures in Fahrenheit degrees and when foot pounds per pound of steam, instead of calories are involved, the last formula becomes:

$$\int_{\tau_0}^{\tau_1} h d\tau = -2563522 \log_e \frac{\tau_1}{\tau_2} + 783\,(\tau_1 - \tau_0).$$

But the independent variable is, in this formula, absolute temperature, and were the initial and final states determined by observations on pressure, which is nearly always the case in actual practice, the temperatures corresponding to the observed pressures would have to be first obtained, either by means of a table or by substitution in a formula quite as complex as the one just given; after which the operations above indicated would then have to be performed. It has therefore appeared to me desirable to obtain a formula which would allow of the direct computation of $\int h d\tau$ in terms of pressures.

Taking the differential coefficient with reference to τ, of the general thermo-dynamic expression for the internal energy from some standard value U_0, we have in the case of water and steam:

$$\frac{dU}{d\tau} = c + \frac{d}{d\tau} \int_{x=0}^{x=1} \tau^2 \left(\frac{d}{d\tau} \frac{p}{\tau} \frac{dv}{dx} - \frac{d}{dx} \frac{p}{\tau} \frac{dv}{d\tau} \right) dx,$$

in which if we make $x = v$, we obtain, without material error:

$$\frac{dU}{d\tau} = C + \frac{d}{d\tau} \left(\tau^2 \frac{d}{d\tau} \frac{p}{\tau} \right) v = C + \frac{d}{d\tau} \left(\tau v \frac{dp}{d\tau} - pv \right)$$

the expression for the variation of internal energy of the water in the state of saturated vapor.

The corresponding variation of external work is

$$-p\frac{dv}{d\tau}d\tau.$$

The thermal equivalent of these two quantities will moreover constitute the entire transfer of heat involved, so that we may write:

$$\int_{\tau_0}^{\tau_1}\frac{dQ}{d\tau}d\tau = \int_{\tau_0}^{\tau_1} C d\tau + A\int_{\tau_0}^{\tau_1}\frac{d}{d\tau}\tau v\frac{dp}{d\tau}d\tau - A\int_{\tau_0}^{\tau_1}\frac{d}{d\tau}(pv)\,d\tau - A\int_{\tau_1}^{\tau_0} p\frac{dv}{d\tau}d\tau$$

The first two terms of the second member of this equation constitute the total heat of evaporation of the liquid from the temperature τ_0 at τ_1.

The experiments of Fairbairn and Tate* upon saturated steam have shown that for temperatures not greatly exceeding 288° Fahr., the specific volume of saturated steam may be approximately expressed by the equation:

$$v = 25{\cdot}62 + \frac{1257605}{p + 18{\cdot}29}$$

p being expressed in millimeters of mercury. Substituting a, b, and c respectively for the constants involved, we obtain:

$$dv = -\frac{bdp}{(p+c)^2}$$

whence

$$\int pdv = \int\frac{-bpdp}{(p+c)^2} = \frac{bp}{(p+c)} - b\log_e(p+c) + c_1 =$$

$$p(v-a) - b\log_e(p+c) + c_1.$$

The corresponding pressures being substituted for the limits of the definite integrals, and writing H_p for the total heats of evaporation in foot pounds at the corresponding pressures, we find finally:

$$\int_{\tau_0}^{\tau_1} h d\tau = \int_{p_0}^{p_1}\frac{dQ}{dp}dp = H_{p_0} - H_{p_1} - \left[a(p_1 - p_0) - b\log_e\left(\frac{p_0+c}{p_1+c}\right)\right]$$

* Proc. Roy. Soc., Vol. 150, 1860, p. 185. Fairbairn, Mills and Mill-work, Vol. i, p. 220.

When we adopt the pound, square foot and Fahrenheit degree, as our units, the values of a, b, and c become the following:

	$a = 0{\cdot}4104.$	$\text{Log } a = \text{T}{\cdot}6132145$
for hyp. log's	$b = 56098{\cdot}7.$	$\text{Log } b = 4{\cdot}7489528$
for Briggs' log's	$b = 129173.$	$\text{Log } b = 5{\cdot}1111713$
	$c = 50{\cdot}93+$	$\text{Log } c = 1{\cdot}7069869$

So that for the specific heat of one pound of saturated steam, sometimes called latent heat of expansion, we have the formula in foot pounds:

$$\int_{\tau_0}^{\tau_1} h\,d\tau = \int_{p_0}^{p_1} \frac{dQ}{dp}\,dp = H_{p_1} - H_p + 0{\cdot}4104\,(p_0 - p_1) + 129173 \log\left(\frac{p_0 + 50{\cdot}93}{p_1 + 50{\cdot}93}\right)$$

To facilitate calculation by this formula, I have computed the following table of approximate values of H_p, on the basis of 1 calorie equal to 424 kilogrammeters; whose approximativeness may be taken as about that of the experiments of Fairbairn and Tate, for which they were adapted.

TABLE.

Lbs. per square inch	Lbs. per square foot	H_p	Lbs. per square inch	Lbs. per square foot	H_p
5	720	874425	75	10800	908614
10	1440	881711	80	11520	909658
15	2160	886369	85	12240	910647
20	2880	889882	90	12960	911597
25	3600	892708	95	13680	912505
30	4320	895126	100	14400	913471
35	5040	897248	105	15120	914206
40	5760	899110	110	15840	915013
45	6480	900816	115	16560	915789
50	7200	902356	120	17280	916536
55	7920	903786	125	18000	917261
60	8640	905080	130	18720	917966
65	9360	906349	135	19440	918649
70	10080	907616			

HOBOKEN, N. J., March 7, 1875.

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